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1927—1928.

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A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

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This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

DISTRIBUTION PUMPING STATIONS OF THE METROPOLITAN WATER WORKS.

BY A. O. DOANE.*

[*Read September 15, 1927.*]

In the year 1893 an act was passed by the Massachusetts Legislature directing the State Board of Health to make an investigation for an additional supply of water for the Boston Metropolitan District, as it had been evident for some time that the capacity of the existing sources of water supply would soon be inadequate.

After careful investigation of all available sources of supply the Board reported in favor of taking the water of the South Branch of the Nashua River at a point in the town of Clinton, building a large reservoir and an aqueduct to utilize this supply in conjunction with existing works of the city of Boston.

In 1895 the Metropolitan Water Act was passed which established a Metropolitan Water District, consisting of Boston and 12 other municipalities, and provided for the appointment by the Governor of three Water Commissioners, constituting the Metropolitan Water Board.

Mr. Frederic P. Stearns who, as Chief Engineer of the State Board of Health, conducted the investigation for a new source of water supply, was appointed Chief Engineer of the Metropolitan Water Board, and the works were designed and built under his direction.

Mr. Dexter Brackett was Engineer of the Distribution Department and had charge of the building of the pipe lines, reservoirs, and pumping stations of the distributing system.

On January 1, 1898, the collecting works, aqueducts and pumping stations of the city of Boston were taken over and thereafter operated by the Metropolitan Water Board and its successors, — the Metropolitan Water and Sewerage Board, created in 1901, and the present organization, known as the Metropolitan District Commission, established in 1919. The work of this Commission is carried on under three main divisions as follows — Water Division, Sewerage Division, and Parks Division.

The Water Division operates the works for supplying water to the

*Water Division, Metropolitan District Commission, Boston, Mass.

Metropolitan District which now consists of Boston and 19 cities and towns with a total population of 1 424 480 in 1926. The principal collecting reservoirs now in use are the Wachusett Reservoir on the Nashua River at Clinton and the Sudbury Reservoir and Framingham Reservoir No. 3 of the Sudbury River system, located in the city of Marlboro and the towns of Southboro and Framingham. Lake Cochituate at Natick is ordinarily held in reserve, but considerable water has been drawn from this source during the past summer.

The water is conveyed to the District by four aqueducts: The Wachusett Aqueduct conveys the water from the Wachusett Reservoir to the Sudbury Reservoir; the Weston Aqueduct conveys water from the Sudbury Reservoir to the Metropolitan District; the Sudbury Aqueduct for conveying water from the reservoirs of the Sudbury River system to Chestnut Hill Reservoir and the Cochituate Aqueduct, which brings the water of Lake Cochituate to Chestnut Hill Reservoir.

All of the water brought to Chestnut Hill is pumped for the supply of the District at the stations located at the Reservoir, while the water conveyed by the Weston Aqueduct is delivered at the terminal chamber at an elevation which is sufficient to give a satisfactory pressure by gravity in a large part of the low-service district served by the large supply mains connected with the terminal chamber.

The average daily consumption of water for the District in 1926 was 138 650 100 gal.; the per capita consumption was 97 g.p.d.

The Water Division operates five pumping stations connected with the distribution system and also two small stations, one in Natick, pumping the water of Pegan Brook to filter beds, and the other at Clinton, pumping the town sewage to filter beds.

Chestnut Hill Pumping Stations.

The principal pumping stations are located at Chestnut Hill Reservoir and are known as No. 1 and No. 2.

Pumping Station No. 1 was built by the city of Boston in 1887. An addition to this building was built and a vertical, triple-expansion, crank and fly-wheel pumping engine was installed therein by the Metropolitan Water Board in 1898. This engine, No. 4, was built by the E. P. Allis Company and has a nominal capacity of 30 m.g.d. The steam cylinders are 30 in., 56 in. and 87 in., and the pump plungers 42 in. in diameter. All have a stroke of 66 in.

The following pumping engines were taken over with the station from the city of Boston, — two horizontal, compound, fly-wheel engines of the Gaskill type, Nos. 1 and 2, each having a nominal capacity of 8 m.g.d. and built by the Holly Manufacturing Company in 1887; and a vertical, triple-expansion, fly-wheel engine, No. 3, designed by E. D. Leavitt and built by the Quintard Iron Works in 1895, having a nominal capacity of 20 m.g.d. The steam cylinders are 13.7, 24.375 and 39 in. in diameter with 72-in.

stroke. The water plungers are 17.5 in. in diameter with 48-in. stroke. The water valves are of the Riedler, mechanically operated, type.

Gaskill engine No. 2 was removed and a cross-compound, crank and fly-wheel, opposed type pumping engine, No. 16, having a nominal capacity of 15 m.g.d., was installed in its place in 1921. This engine was built by the Worthington Pump and Machinery Corporation. The steam cylinders are 23 and 54 in. and the pump plungers 23¾ in. in diameter; the stroke for all is 36 in.

The Leavitt engine, No. 3, pumping against a head of 137.48 ft. with a steam pressure of 175.7 lbs. at the throttle valve, gave a duty of 150 045 000 ft. lbs. per 100 lbs. of coal, or 145 470 000 ft. lbs. per million British thermal units.

The Allis pumping engine, No. 4, gave a duty of 176 051 500 ft. lbs. per 1 000 lbs. of steam, or 157 002 500 ft. lbs. per million b.t.u. when pumping against a head of 140.35 ft. with steam pressure at throttle 185.47 lbs. by gage.

The Snow-Holly cross-compound engine, No. 16, gave a duty of 147 756 000 ft. lbs. per 1 000 lbs. of steam at the contract trial, when pumping against a head of 150.68 ft. with steam pressure of 180.8 lbs. at the throttle.

The coal house is equipped with a bucket elevator which conveys coal from a track hopper to a system of chutes which distribute the coal to the bins.

The boiler plant consists of 5 vertical fire tube boilers of the Dean type, all designed for 185 lbs. working steam pressure. The shells are 98 in. in diameter and 24 ft. high; the tubes are 2 in. in diameter and 15 ft. long; two of the boilers have 392 tubes each, the other three have 400 tubes each. The height of the furnace above the grate is about 8.5 ft. The boilers are fitted with manholes, and all interior parts may be easily inspected and cleaned. These boilers are very efficient under our working conditions; carefully conducted tests have shown that this type of boiler has an efficiency of 80 per cent. for the boiler and furnace, and 83 per cent. for the combined boiler and economizer. An economizer having 168 4-in. tubes is used to heat the boiler feed water. The chimney is 150 ft. high.

Pumping Station No. 2 was built by the Metropolitan Water Board in 1900. The exterior walls are of Bedford limestone. The engine room is 134 ft. long and 60 ft. wide. The boiler room is 62 ft. by 40 ft. and the coal house 89½ ft. by 48 ft. There are also a dynamo room 38 ft. by 17 ft. and a tower 19 ft. square, containing a steel equalizer tank, 13½ ft. in diameter and 33 ft. high, connected to the discharge pipes of the low-service pumps. The chimney is 125 ft. high.

The pumping equipment consists of three 35-m.g.d. and one 40-m.g.d. engines, all built and installed by the Holly Manufacturing Company, now a division of the Worthington Pump and Machinery Corporation. The engines are all of the vertical, triple-expansion, crank and fly-wheel type.

The 35-m.g.d. engines, numbered 5, 6 and 7, are used for low-service pumping against an average head of about 46 ft. The steam cylinders are 17, 31¼, and 48 in. and the pump plungers 37 in. in diameter. The stroke is 60 in. for both pistons and plungers.

The 40-m.g.d. pump, No. 12, is used for high service and pumps against an average head of about 126 ft.; the steam cylinders are 32, 60, and 90 in. and the plunger 43.5 in. in diameter and the stroke is 60 in. It was installed in 1911.

On the contract trial the three low-service engines tested together, with 150 lbs. steam pressure by gage at the throttle valve, pumping against an average head of 44 ft., gave a duty of 157 349 000 ft. lbs. per 1 000 lbs. of steam. The 40-m.g.d. pumping engine, No. 12, pumping against a head of 132 ft., gave a duty at the contract trial of 175 066 000 ft. lbs. per 1 000 lbs. of steam with superheat of 15°F. and with a gage pressure of 151 lbs. per sq. in. at the throttle valve.

All of the pumping engines at Pumping Stations No. 1 and No. 2 are equipped with surface condensers except the old Gaskill engine No. 1 which has a jet condenser.

The electric energy used for lighting and power purposes, including the machine tools in the machine shop and the coal conveyer, is generated by two 35-k.w. units installed in pumping station No. 2. Each of these units is amply large to handle the work and there is another one of 25-k.w. capacity at pumping station No. 1 which is held in reserve. All of the generating units are of the direct-connected, steam engine-driven type. The stations are connected by an underground cable so that any unit may be used to do the work.

The boiler plant consists of five vertical, fire tube boilers of the Dean type. Three of these are 98 in. in diameter and 25 ft. high and two are 109 in. in diameter and 24 ft. high. The 98-in. boilers have 384 2-in. tubes 15 ft. long and the 109-in. boilers have 484 tubes of the same diameter and length. There are two economizers in use for heating the boiler feed water. Each has 144 4-in. cast-iron tubes.

Ashes are removed by means of steel dumping cars which are run into a tunnel under the boiler room floor. The cars are loaded through chutes connected with openings in the floor in front of the ash pits of the boilers. The cars are brought to the ground level outside of the station by an hydraulic elevator and run over tracks to the dump, a distance of about 400 ft.

The coal is brought into the coal house, which has a capacity of 1 000 tons, in bottom dump railroad cars. These run in on a trestle 15 ft. above the floor, and the coal is dumped and trimmed if necessary.

All of the water pumped at the Chestnut Hill stations is drawn from Chestnut Hill Reservoir. The larger part, amounting to 16.11 billion gal. in 1926, was pumped for the supply of the Southern High Service District, while 4.39 billion gal. were pumped for the low-service requirements,

supplementing the gravity flow from the Weston Aqueduct supply mains. The low-service pumps are operated on a regular schedule, changing the pressure at frequent intervals in order to give a satisfactory and fairly uniform pressure in the main business district of Boston. In the night the gravity pressure alone is sufficient and the pumps are shut down. In case of a large fire the pumps are used to increase the pressure in the mains.

Spot Pond Pumping Station.

The water for the Northern High Service District is pumped at the Spot Pond Pumping Station in Stoneham.

The exterior walls of the building are gray Roman brick with trimmings of buff Indiana limestone and a base of pink Milford granite. The roof is covered with red tiles.

The engine room is 105 ft. by 60 ft., the dynamo room 49 ft. by 16 ft., the boiler room 53 ft. by 49 ft., and the coal house 71 ft. 8 in. by 40 ft., having a storage capacity of 1 000 tons. The chimney is 125 ft. high.

There are three pumping engines in the engine room. The oldest, No. 8, is a 10-m.g.d. vertical, compound, crank and fly-wheel engine, designed by E. D. Leavitt and built and installed in the Mystic Pumping Station of the Boston Water Works in 1895, by the Blake Manufacturing Company. It was removed to its present location in 1899 and is now used as a reserve pump. The Leavitt engine has steam cylinders 21 and 42 in. in diameter. The pump plungers are of the differential type with diameters of $14\frac{7}{8}$ and 21 in. and both pump plungers and steam pistons have a stroke of 48 in.

No. 9 engine has a nominal capacity of 20 m.g.d.; it is a vertical, triple-expansion, crank and fly-wheel machine and was designed, built and installed in 1900 by the Holly Manufacturing Company of Lockport, N. Y. The steam cylinders are 22, 41.5, and 62 in. and the water plungers 30.5 in. in diameter, and both pistons and plungers have a 60-in. stroke. This engine gave a duty at the contract trial of 172 405 000 ft. lbs. per 1 000 lbs. of moist steam, when pumping against a head of 125 ft. with a steam pressure of 151 lbs. by gage at the throttle valve. This engine pumped nearly all the water delivered from this station for 26 years and is still in good condition.

Engine No. 17 was built and installed by the Worthington Pump and Machinery Corporation and was first put in service in January, 1925. This engine has a capacity of 20 m.g.d. and is of the horizontal, cross-compound, crank and fly-wheel, opposed type. The steam cylinders are 24 and 54 in. and the pump plungers $26\frac{1}{2}$ in. in diameter, and all have a 36-in. stroke.

The engine gave a duty at the contract trial of 141 223 000 ft. lbs. per 1 000 lbs. of saturated steam, when pumping against a net head of 125.36 ft. with an average steam pressure of 151 lbs., by gage, at the throttle valve.

All of the engines are run condensing, surface condensers being used.

The boiler room contains four vertical, fire tube boilers of the Dean type; three of these are 92 in. in diameter and 25 ft. high and one is 98 in. in diameter and 24 ft. high. The smaller boilers were designed for 165 lbs. and the larger one for 185 lbs. working steam pressure. There is a 144-tube economizer for heating the boiler feed water by means of the flue gas.

As the station is about a mile from the railroad, all of the coal has to be brought in trucks which drive into the coal room and dump the coal, through openings in the floor, into the bins in the basement. The ashes are handled by a steam jet conveyer which blows them into a steel storage tank in the coal room; trucks are run under this tank and loaded by opening a gate at the bottom of the tank.

There are three electric generating units. The largest one consists of a horizontal steam engine, direct-connected to a 15-k.w. generator. There is also a Westinghouse steam turbine-driven generator of 1½-k.w. capacity and a 2½-k.w. generator driven by an 18-in. Pelton water wheel.

The water pumped at this station, amounting to a daily average of 10 194 000 gal. in 1926, is drawn from Spot Pond, and the greater part is delivered into the Fells Reservoir having a capacity of 41 353 000 gal.; pipe lines from this reservoir distribute the water to the higher parts of the district north of Boston. A small part of the water pumped at this station, averaging about 560 000 g.p.d., is raised to Bear Hill Reservoir, which has a capacity of 2 452 000 gal. and is 29 ft. higher than Fells Reservoir, for the supply of the town of Stoneham.

An hydraulic lift gate on the discharge main is partly closed. This increases the pressure in the main between the gate and the pump; there is a connection fitted with a check valve in this section of the discharge main through which water is forced into a pipe line which conveys the water to Bear Hill Reservoir. The check-valve prevents the water from flowing back when the engine is pumping against the Fells Reservoir head. The pump is run at full capacity, and the high head pumping is continued only long enough to fill Bear Hill Reservoir to the required height. The pressure is then lowered, and Stoneham is supplied by gravity until it is necessary to repeat the operation. This is done once in 24 hours. Owing to the high efficiency of the large pump and the small amount of water needed for this service, it is more economical to operate in this way than to use a small independent pump for this service.

Arlington Pumping Station.

The higher parts of the town of Arlington and Belmont and the whole of the town of Lexington are supplied from this station. The water is taken from a 20-in. pipe, which connects with the Weston Aqueduct supply main and is delivered through a 16-in. force main to a steel reservoir having a capacity of 1 995 000 gal. At Arlington the net head pumped against varies with the rate of pumping from about 270 ft. to about 300 ft. The

station is built of brick; the engine room is 48 ft. 2 in. by 40 ft. 4 in. and the boiler room 40 ft. 4 in. by 35 ft. 2 in.

The pumping equipment consists of three engines, Nos. 10, 11, and 15. No. 10 is a horizontal, cross-compound, crank and fly-wheel pumping engine, built and installed in 1907 by the Allis-Chalmers Company. The engine has a nominal capacity of 1.5 m.g.d. The steam cylinders are 14 and 28 in. and the pump plungers 8½ in. in diameter. All have a stroke of 18 in. The engine showed a duty at the full capacity contract trial of 115 959 370 ft. lbs. per 1 000 lbs. of dry steam when pumping against a head of 290 ft. with steam pressure of 125 lbs. at the throttle.

No. 11 is a horizontal, duplex compound, direct-acting pumping engine of the same capacity as No. 10; it was built and installed by the Blake and Knowles Steam Pump Works in 1907. The steam cylinders are 11 and 22 in. and the pump plungers 12 in. in diameter, both having a stroke of 18 in. This engine gave a duty at the contract trial of 60 727 400 ft. lbs. per 1 000 lbs. of dry steam, when pumping against a total head of 290 ft. with steam pressure of 125 lbs. at the throttle. This engine has always been used as a reserve unit.

No. 15 is a steam turbine-driven, centrifugal pumping unit having a nominal capacity of 3 m.g.d. The unit was furnished and installed by F. A. Mazzur and Company in 1918. It consists of a Moore multi-stage steam turbine of 260 brake h.p., rating at 125 lbs. steam pressure, connected through speed-reducing gears with two Allis-Chalmers single-stage, 8-in. centrifugal pumps in series. The nominal speed of the turbine is 5 000 r.p.m. for the rated capacity against a head of 320 ft. The surface condenser is of the water-works type, with a cooling surface of 600 sq. ft. and was built by the Wheeler Condenser and Engineering Company. The independent air pump is of the Wheeler-Edwards, suction, valveless, crank and fly-wheel type. The unit gave a duty at the full capacity contract trial of 82 359 200 ft. lbs. per million b. t. u. (contract basis), equivalent to 89 965 200 ft. lbs. per 1 000 lbs. of moist steam.

This unit was installed for reserve and peak load purposes. It is located between engines 10 and 11, and no reciprocating pump of sufficient capacity could be installed in such a small space. As the average daily amount pumped at this station varies from a minimum of about 1 m.g.d. in winter to a maximum of over 2 m.g.d. in very hot, dry weather, it was necessary to have a unit of this capacity in order to be safe in case one of the smaller pumps should be out of commission during a period of high consumption.

Coal is received by cars which run in on a side track, part of which is built on the roof of the coal room, and the coal is dumped through trapdoors into the bins.

The boiler plant consists of 3 horizontal, return, tubular boilers, designed for 160 lbs. steam pressure and set in brickwork; the boiler shells are 54 in. in diameter and 17½ ft. long and each boiler has 60 3-in. tubes 17 ft. long.

Hyde Park Pumping Station.

This station serves the Southern Extra High Service Area which is too high to obtain a satisfactory pressure from the Southern High Service System.

The pumps draw water from the Southern High Service mains and deliver it into the Extra High Service pipes which are connected with a steel reservoir on Mt. Bellevue in West Roxbury, having a capacity of 2.5 million gal.

The pumping station is a brick building containing an engine room 59 ft. 8 in. by 42 ft. 8 in., a boiler room 39 ft. 4 in. by 37 ft. 8 in. and a coal room with a railroad siding on top, as in the case of the Arlington Pumping Station.

The pumping machinery consists of two horizontal, cross compound, crank and fly-wheel pumping engines of the extended type, Nos. 13 and 14, each having a nominal capacity of 3 m.g.d. They were built and installed in 1913, by the Laidlaw-Dunn-Gordon Company, now a subsidiary of the Worthington Pump and Machinery Corporation.

The steam cylinders are 13 in. and 27 in. and the pump plungers 11½ in. in diameter. All have a stroke of 24 in. The air pumps are operated by the main engine. The surface condensers are of the water-works type.

At the contract trial the engines showed the following duties when pumping at a rate of 3 m.g.d. against a head of 140 ft. with steam pressure of 125 lbs. at the throttle: Engine No. 13, 119 795 000 ft. lbs., and Engine No. 14, 121 022 000 ft. lbs. per 1 000 lbs. of dry steam.

The boiler plant consists of two horizontal return tubular boilers in brick settings. The boilers are 54 in. in diameter and 14½ ft. long and each boiler has 62 3-in. tubes 13.92 ft. long; electricity is furnished by a small, vertical engine-driven generator.

Ten of the 16 pumping engines in the distribution stations of the Metropolitan Water Works have been in service over 20 years; Engine No. 1 for 40 years and Numbers 3 and 8 for 32 years. They are now operating satisfactorily but are not as economical in operation as the modern engines. The boilers are fitted with charcoal-iron tubes, and very few tubes have been removed. It is probable that the allowable pressure on the older boilers will soon be reduced, and if the reduction is such that the engines cannot be economically operated it will be necessary to provide new boilers.

The policy of buying only first-class equipment and maintaining it properly while in service has proved not only truly economical, but tends to avoid costly repairs and consequent interruption of the service. While economy in operation is highly desirable, it is not considered advisable to jeopardize dependable operation of a vital public service to save a few dollars.

Mr. William E. Foss is Director and Chief Engineer of the Water Division. Mr. Charles P. Stuart is Superintendent of Pumping Stations, and the writer is in charge of the mechanical engineering work of the division under the general supervision of Mr. Foss.

DISCUSSION.

WILLIAM W. BRUSH.* I can't say very much on the basis of modern equipment of our pumping stations. We have several pumping stations, and we have some very antiquated machinery. I would like to ask Mr. Doane if there is a program as to the replacement of any of the reciprocating pumping installations. Some of the Metropolitan pumps are now pretty well along in years. Have they reached the point where the division is really considering replacing them; and if so, with what type of pump?

MR. DOANE. That is quite a problem. Of course these pumps are of a somewhat antiquated type now. At the same time the vertical, triple type and the cross-compound type are very efficient machines. We have found from making studies lately that the triple-expansion pump is just about out of the picture, as far as replacement is concerned, because of the extremely high cost. At the Spot Pond Pumping Station we studied the matter, not as a replacement but as an addition; the same line of reasoning, however, applies. We considered the Diesel engine, steam turbine operation, a vertical triple and a cross-compound pump. The vertical triple is a 20-m.g.d. pump, costing $65 000 when installed. At the present time the lowest price for a pump of this type and capacity, but not as good as the one in service, is $170 000; one concern asked $220 000. As the ratio of duty is in the neighborhood of 140 million for the cross-compound pump, and 170 million for the vertical triple-expansion pump, it is easily seen that the vertical cannot pay its way; i.e., there is not enough difference in efficiency to overcome the great difference in fixed charges. The steam turbine was considered, and theoretically there is a slight advantage in its favor, but the uncertainty about its life, the gear troubles, noise and wear, the necessity of reblading the turbine from time to time, and the character of the operating force, as well as the type of boiler equipment required, seem to turn the scale in favor of putting in the cross-compound pump. We therefore put in a 20-m.g.d. cross-compound engine in the place where it was originally intended to have a vertical engine. We had to make a little change in the floor plan and put in more of a foundation, but the new pump works very well, and I think that it was a good choice. In comparison with the compound engine, the vertical has many more bearings, is three stories high, and takes an engineer and an oiler to run it, whereas you can run the cross-compound with just an engineer. I think the cross-compound maintains its efficiency somewhat better than the vertical pump.

*Chief Engineer, Bureau of Water Supply, New York, N. Y.

When a capacity greater than 20 m.g.d. is required in steam operation, it seems to me that the turbine should be used, as the reciprocating steam pump has very decided limits in capacity.

As far as electric operation is concerned, where current is obtainable for a cent or less per k.w.h., it becomes a very formidable competitor, which should receive very careful attention when properly safeguarded.

A good deal of attention must be paid to individual conditions. If you own a going plant, with a large and costly investment in steam, if you have an operating force that is familiar with steam, and if your replacements and extensions are within the limits within which steam gives economical service, it seems to me that it is well to continue with steam. In any event, I can hardly conceive of anything that is more dependable than steam; and dependability is a great thing in municipal water supply.

MR. BRUSH. That was the information I wished to have Mr. Doane record.

It may be of some interest to state that, to replace a steam plant on Staten Island, pumping 4 m.g.d. against a head of 250 ft., the electric drive is to be used as regular service with a gasoline engine as a stand-by. The current will come from two independent power stations, but we felt that we could not rely upon the electric current and that the cheapest unit that we could put in as a stand-by was a gasoline engine.

In the New York pumping plants the general trend is towards electricity. In one plant on Long Island two 20-m.g.d. steam turbines are now ready for test, but within the city limits the electric power is considered desirable, and the difference in operating costs under New York City conditions of labor cost is very slight.

Where the difference has been, perhaps, not more than 5 per cent. in comparative cost, we have turned to electricity rather than continuing with steam or installing oil engines. I believe the greater part of the New York equipment will be electric-driven within the next few years.

Last fall New York had to put in a 60-m.g.d. plant in a hurry, and in about two weeks' time a contract had been made whereby the plant was to be finished in two months from the time the contract was made and at a cost of about $45 000 for the pumps, motors, and transformers installed in place. The pump chamber was available, but that was all. As the emergency conditions were relieved by rainfall, overtime work was eliminated, and the installation of the plant required about three months' time.

Electric current has not always been available, and the station has been out of service two or three times within the last six months on account of interruptions in the current. On the other hand, the Edison Company did not make any special effort to give us continuous service because it was told that such service was not at all essential. The water is pumped into the Catskill Tunnel, and therefore the regular Catskill supply could take the place of this supply at any time if there was any interruption. The question of interruption of service is important in determining what power

is to be selected. Steam is, in the writer's judgment, the most reliable from the point of view of continuity of service.

HENRY T. GIDLEY.* I would like to ask Mr. Brush what price he has to pay for the electric current.

MR. BRUSH. The New York price varies. I think the last price that we had quoted is about a cent per k.w.h. and that 1.2 cents is about as high as we have to pay. In Manhattan, at our 79th Street pumping station, where we are about to put in an electric drive, the price works out between 1.1 and 1.2 cents; and it showed almost the same price for the water pumped for steam, for Diesel engine, and for electricity. So that we decided to go ahead on the electric drive.

In connection with reliability of electricity, we have had the high-pressure system under electrical drive since 1907 in Manhattan, and there has never been a failure of the electric current during these twenty years. The station is hooked up by three or four independent cables to about six generating stations, and there is a penalty of $500 a minute if the current does at any time fail.

* Superintendent, Fairhaven Water Co., Fairhaven, Mass.

BOSTON'S HIGH-PRESSURE FIRE SYSTEM.

BY E. E. WILLIAMSON.*

[*Read September 14, 1927.*]

General Outline of System.

The City of Boston possesses a distribution system of cast-iron mains, supplying hydrants only, which provides excellent fire protection to a limited area that includes the greater portion of the congested value district. The system is normally under pressure from the domestic system. Higher pressures are obtained by pumping from either of two pumping stations, taking suction from the Southern Low Service; in an emergency the supply at each station may be obtained from the Southern High Service or from salt water in Boston Harbor. Design, construction, and maintenance of the distribution system are under the Department of Public Works; operation of the pumping stations is under the Fire Department. The system was placed in service, December 19, 1921.

Pumping Stations. Both stations are under the general supervision of the author, and in charge of W. C. Bailey, Superintendent of High-Pressure Stations and Hydrants. Operation is in three shifts of two men in each station. There are substitute operators in the fire department, and call bells are installed to summon assistance from the operating force of the power house in which the station is located, in case this aid should be required.

The system is divided for pumping operation into two divisions: Station 1 starts on receipt of alarms from Division A, and Station 2 from Division B. On receipt of alarms, one pump is started and a pressure of 125 lbs. is maintained. Additional pressure is given on receipt of telegraphic signal. A second pump is started when necessary to maintain the pressure required, and pumping at the other station would follow on orders from the station operating. Tests are made daily, each of the four pumps raising the pressure to 125 lbs. One of the stations operated for about 500 alarms annually. During this period the maximum demand did not require the operation of more than 2 pumps.

Signaling System. Alarms are received in each pumping station on the usual tapper and gong circuits of the municipal fire-alarm system, with a perforating register and small gong on the tapper circuit and a gong on the gong circuit. For signaling from fires three special circuits connect telephone jacks in fire-alarm boxes in the high-pressure zone to a Morse key, telephone jack, and relay at fire-alarm headquarters; the relays operate registers, time stamps, flash lights and sounders. Portable tele-

*Superintendent, Maintenance Division, Boston Fire Department.

graph and telephone instruments, carried by chief officers responding in high-pressure districts, are used for code signals for increase or decrease in pressure. These are repeated over a special alarm circuit connecting fire-alarm headquarters with both stations; Morse keys and relays operating perforating registers and red flash light are provided at headquarters and at each station; headquarters has a tapper and time stamp and each station an 8-in. turtle gong. Orders from one station to the other, for the operation of additional pumps, are transmitted directly over this circuit. Fire-alarm switchboards in the pumping stations are of slate, with metal mountings; standard fire-station keys and switches provide testing facilities on each board. A single telephone line connects the fire department telephone switchboard in headquarters with both stations.

All orders are transmitted by telegraph, using special code signals for purposes of records; telephones are used only for confirmation. Signals are repeated back for verification.

Station No. 1. This station is located in the Lincoln Power Station of the Boston Elevated Railroad Company at Commercial and Battery streets.

The equipment includes two Worthington three-stage centrifugal pumps each direct-connected to a Westinghouse steam turbine, operating at 1 165 r.p.m., and 175 lbs. steam pressure. Specifications required a discharge from each pump of 3 000 g.p.m. at 300 lbs. pressure and 4 550 g.p.m. at 200 lbs., with a suction pressure of 40 lbs.

Two 16-in. suction lines extend from a 16-in. Boston Southern Low Service main in Commercial Street to the suction header in the station; one of these lines has a 16-in. connection, ordinarily closed, to a 16-in. Southern High Service main in Commercial Street; low-service pressure is 50–60 lbs.; the high service is 80–90 lbs. An emergency salt-water supply, with maximum lift of 15 ft., is provided by a 16-in. line, about 20 ft. long, which extends from the suction header to a well supplied by a 6-ft. masonry tunnel from Boston Harbor used to supply condenser water for the power station.

A centrifugal vacuum pump, driven by a 10-h.p. motor, with 75-gal. priming tank, is provided for priming the fire pumps and is tested bi-weekly. Two 16-in. lines, each equipped with a Venturi meter, extend from the discharge header to 20-in. lines of the distribution system. Suction and discharge piping are well equipped with gate-valves which are electrically operated. Regulating valves are installed between the suction and discharge of each pump by means of which pressures are controlled from the operating board, where gages are installed and from which pumps and valves are operated. Steam is supplied through an 8-in. loop connecting to each end of the steam header in the boiler room of the power station, each pump having a 5-in. gated branch line connecting at points between valves in the loop. There are 20 Babcock and Wilcox boilers, with a total output of 10 344 h.p., used primarily to supply the 5 generator engines of the power company. Boilers have forced draft, and an ample supply of steam is constantly available.

The power station is a large, high, two- and three-story, fire-proof building, with mild exposures mainly unprotected. Chemical extinguishers are located about the building, and a 600-gal. fire-pump supplies standpipes and hose in the building and in the frame coal bunker 65 ft. in rear of station. The high-pressure fire pumps are in a basement room, 20 x 48 ft., on a concrete floor 9 ft. below ground level; the walls are 12-in. brick and concrete; the roof is 5-in. concrete on steel I-beams. Walls are

TABLE 1.

RESULTS OF TESTS OF PUMPS.

Pump.	Speed, r.p.m.	Discharge, g.p.m.	Discharge Pressure, lbs. per sq. in.	Suction Pressure, lbs. per sq. in.
Station 1.				
Pump 1	1 099	4 676	201	41
	1 179	3 100	301	41
Pump 2	1 163	5 164	209	41
	1 170	3 114	300	42
Both Pumps:				
1	1 165	10 266	201	31
2	1 159			
Station 2.				
Pump 1	1 051	4 413	202	43
	1 035	3 141	298	41
Pump 2	1 060	4 407	200	40
	1 035	3 000	304	41
Both Pumps:				
1	1 038	6 580	292	40
2	974			

not proofed against the wash water from boilers; the entrance from outside of building is at one end of the pump room; an emergency exit at the other end has a vertical ladder leading to an air-compressor room. The fire hazard is very slight.

Station No. 2. This station is located in the sub-station of the Edison Electric Illuminating Company at Pearl Street and Atlantic Avenue.

Its equipment includes two Worthington, four-stage centrifugal pumps, each direct-connected to a 750 h.p., 235-volt, 2 580 ampere, 1 000 r.p.m., direct-current Westinghouse motor. Specifications required a discharge from each pump of 3 000 g.p.m. at 300 lbs. pressure and 4 350 g.p.m. at 200 lbs., with 40 lbs. suction pressure. The results of tests are shown in Table 1.

Two 16-in. suction lines extend from a 16-in. Southern Low Service main in Atlantic Avenue to the suction header in the station; one of these lines has a 12-in. connection, ordinarily closed, to a 12-in. Southern High Service main in Atlantic Avenue. An emergency salt-water supply, with

maximum lift of 15 ft., is provided by a 16-in. line, about 20 ft. long, which extends from the suction header to a 12 x 14 ft. wooden tunnel from Boston Harbor used to supply condenser water for the engines in the power station. Two vacuum pumps for priming the fire pumps are provided, and are tested bi-weekly. Two 16-in. lines, each equipped with a Venturi meter, extend from the discharge header to the distribution system, each connecting with a 20-in. main in Atlantic Avenue. Pressure-regulating valves are installed as in Station No. 1, and control of pumps and valves is from an operating board, where gages and electric meters are installed. A recording pressure gage maintains a continuous record of the pressure in the distribution system.

Power for operating the pumps is obtained form the Edison Company. Cables extend from pump room to operating room of the sub-station. In this station are four 1 600-k.w. and two 800-k.w. direct-current generators operated by compound engines supplied with steam from 19 boilers, aggregating 8 400 h.p., and also a 1 000-k.w. and two 800-k.w. motor generators.

The steam-driven generators are operated only during the day, but 6 to 10 boilers are constantly under steam. The motor generators receive current at 6 600 volts alternating current from the main generating station of the Edison Company, on L Street, South Boston, and deliver at 250 volts direct current. There are three underground transmission lines, over two separate routes, from the L Street station, any two of which can operate the entire motor generator capacity. Ten direct-current tie lines from seven sub-stations can, in emergency, supply 1 500 to 1 800 k.w. to the Atlantic Avenue sub-station. Two storage batteries, adjacent to the sub-station, have a combined capacity of 9 470 ampere hours.

The power station is a large, high, one-story, fire-proof building with windows protected against mild exposures. Chemical extinguishers are distributed about the station. Pumps are in a substantial brick room, 32 x 58 ft., with concrete roof and floor and wired glass windows. The fire hazard is very slight.

Distribution System. The larger lines which radiate from the two pumping stations generally connect en route with alternate lines of pipe. Most of the mains are within the congested value district, and the system protects about 95 per cent. of it. The minimum size of mains is 12 in. The average length of this size between cross-connections is 640 ft., and 1¼ miles are in dead ends. Mains are laid with cover of 5 ft. No trouble has been caused by frozen mains.

The high-pressure fire service is bounded as follows: Park Square, Eliot Street, Stuart Street, Kneeland Street, Atlantic Avenue, Dewey Square, Summer Street, Dorchester Avenue, Congress Street, Purchase Street, Pearl Street, Atlantic Avenue, Richmond Street, Commercial Street, Causeway Street, Portland Street, Chardon Street, Hawkins Street,

Sudbury Street, Howard Street, Somerset Street, Beacon Street, Tremont and Boylston streets.

Sixteen and eight-tenths miles of high-pressure mains are in service, with a total of 451 high-pressure hydrants covering an area of approximately 1 sq. mile.

Pipes. On January 1, 1927, the mileage of mains was 16.8, of which 4.96 were 12-in.; 7.18 miles were 16-in., and 3.81 miles were 20-in. The oldest pipes are 4 300 ft. of 12-in., installed in 1898; the remainder have been laid since 1912.

All pipe is cast iron, purchased under well-drawn specifications and of a design especially suited for high-pressure work; it was hammer-tested at the foundry under a hydrostatic pressure of 600 lbs. The joints are of special design, with two grooves in both hub and spigot; an alloy of lead and tin, with antimony added in some earlier installations, was used where unbalanced pressures exist; by test these joints were found to be sufficiently strong not to require tie-rods. At the time of inspection leakage was about 32 000 g.p.d.

Gate Valves. Valves are of the solid wedge type, bronze mounted, set in brick vaults, with markers on nearby walls. Two or three valves are installed at intersections, with intermediate valves, so that in general not more than three hydrants would be affected by a single break. The average length of mains between valves is 400 ft. Valves are regularly inspected, and record is kept of their operation and condition.

Hydrants. On January 1, 1927, there were 451 hydrants in service. They are of a specially designed post type, opening against the pressure, with 6½-in. valve opening and 8-in. gated connections to main. Hydrants have four 2½-in. outlets, with an independent gate on each. Along the pipe lines the average spacing of hydrants is 150 ft., and the average area served by each hydrant in the congested value district is 40 000 sq. ft. Hydrants are used only for fire fighting. They are regularly inspected, and special attention is given those used during freezing weather.

Improvements. Extensions of the distribution system are made each year. During the past three years 4.31 miles have been added.

The system, as designed, contemplated an additional pump in each of the two stations, and a third station with two pumps to be located in the Stuart Street sub-station of the Edison Electric Illuminating Company. The Stuart Street location is not obtainable now, and no funds are available for increasing the capacity of the existing stations.

Conclusions. The High-Pressure Water Supply System is a protective feature of great value to the fire department, in that it permits the rapid concentration of a large number of powerful streams within the area protected and, lessening the number of engine companies that would ordinarily be required, increases the effectiveness of the department in protecting other parts of the city, should simultaneous fires occur.

The fresh-water supply is ample under ordinary conditions and a salt-

water supply from Boston Harbor is provided for emergencies. The fire hazard of the pumping stations is slight. Ample sources of power are provided and pumping equipment is of a satisfactory type, well maintained and effectively operated. Pumping capacity is not ample for full requirements and does not provide for the unreliability of units out of service for repairs. The distribution system has careful supervision and maintenance. It does not provide its maximum protection to all portions of the congested value district and is jeopardized by a congestion of underground construction. The system is well equipped with gate valves, and hydrants are of a good type and closely spaced. The system is regularly used by the fire department, and its effectiveness warrants the installation of additional pumping capacity.

TABLE 2.

OPERATION OF HIGH-PRESSURE STATIONS.

	Total.	Station 1.	Station 2.
First alarm boxes	124	54	70
Total starts, 1922–1926	2 071	1 205	866
Yearly average starts	414	241	173

DESCRIPTION OF HIGH-PRESSURE HYDRANTS.

The Public Works Department of the City of Boston has adopted, for its high-pressure fire service, a special hydrant. Simplicity of design, reliability of operation, freedom from damage by abuse, and low friction losses are the advantages claimed for this type of hydrant.

The hydrant was designed for a normal delivery of 2 000 g.p.m. For the friction loss test a maximum of 3 000 g.p.m. was obtained, and during the fireboat test 3 600 g.p.m. passed through the hydrant. The hydrant consists essentially of a pot or valve casing, barrel, head hood or cover for the latter, main valve, auxiliary valve and independent outside valves bolted to the head. The main valve, located in the top of the pot of a conical horizontal seat, having an opening $6\frac{1}{8}$ in. in diameter, opens against the pressure with a vertical travel of about $2\frac{3}{8}$ in. The valve and its stem are made up into a rigid structure having a square guide in the bottom of the pot and a stationary operating nut at the top of the head.

The auxiliary valve is an inverted cock bolted to the side of the pot, the three ports or passages in the body leading, respectively, to the pot below the main valve or service pressure, to the pot just above the main valve, and to waste, generally extended to the adjacent sewer. The annular space in the bottom of the cock is at all times connected with the service pressure, which automatically keeps the plug tight against the seat. This valve is operated by a covered stem extending along the side of the barrel.

To the top of the barrel is bolted a head with four openings, each $3\frac{1}{8}$ in. in diameter, and counter-bored on its face to receive a $2\frac{1}{2}$-in. independent gate valve of special design, bolted to the head and having a $2\frac{1}{2}$-in.

male nozzle projecting beyond its seat. The valve is fitted with a loosely hung gate or disc, which seats with the internal pressure, and a valve stem of Monel Metal, squared at the top to receive a portable operating handle T-shaped, with a vertical riser on one of its arms to facilitate its rapid operation. All four valves can be operated simultaneously if desired.

When out of service, the head is completely covered by a pressed steel hood, weighing about 18 lbs. with a guide to engage the head bracket, and on one side of its base it has a pocket with slotted flange to receive the auxiliary valve nut. On the top of the hood is a hood nut, which engages the inclined top flanges on the top of the thrust collar of the head, when rotated about a quarter turn, and wedges the hood and bracket securely together.

The sequence of operation to put the hydrant in commission is as follows: Rotate, with the end of the wrench handle, the auxiliary valve nut as far as possible, or about a quarter turn; this closes the waste and opens the by-pass in the auxiliary valve. Reverse the wrench and rotate the hood nut as far as possible, or about a quarter turn; this releases the hood from the head. Remove the hood, putting it in any convenient place on the sidewalk, out of the way. By this time the pressure in the barrel and against the seats of the independent valves is practically the same as in the service pipe, and the main valve can be opened by its operating nut with very little effort and as rapidly as desired until wide open. To the nozzle of each independent valve is secured, by spanner, a combination fitting of special design, suggested by E. M. Bynington, former Superintendent of the Boston Fire Department Repair Shop. This fitting weighs about 10 lbs. and comprises a piezometer ring and pressure gage, a drain valve and a 2½-in. male threaded outlet to which may be attached a 3-in. hose with 2½-in. coupling. The independent valves are then opened as required.

The varying pressures desired for the different hose lines from the hydrant are regulated by the amount of opening of each independent valve, and, with the special operating handles, any change in pressure for any line can be brought about very rapidly.

To put the hydrant out of service the independent valves are closed, hose lines and combination fittings are removed, the main valve is closed, the hood is placed over the head in its proper position, the auxiliary valve nut is turned a quarter turn, or as far as possible, thus closing the by-pass and opening the waste, and the hood nut is rotated a quarter turn, or as far as possible, securing the hood to the head.

The main valve nut and the hood nut are the same size and are operated by the standard hydrant wrench socket. The auxiliary valve is operated by the handle of the hydrant wrench. The independent valves have the special wrench described above, one or more of which can be permanently stored within the hood. The direction of rotation for all valves and for the hood nut is the same as for the Boston Post Hydrant, namely from right to left.

LEAKS AND LITIGATION.

BY GEORGE H. FINNERAN.*

[*Read September 13, 1927.*]

LEAKS.

In the distribution of water, it is the aim of those in charge of operation to confine the flowing water to the conduits provided and to allow its issue only at controlled outlets to supply the uses of legitimate consumers. Frequently, however, despite most scrupulous care, water issues from the conduit or pipe through holes, cracks, or defective controlling mechanisms, and thereby fails to serve the purpose for which it was collected and conserved. Such an occurrence is commonly known as a *leak*.

The water superintendent may well say of leaks, "Like the poor they are always with us." They are his continual worry. They vary in volume; some are small, some large. In case of the latter, when they are sudden and more or less explosive in nature, they are expressively termed *breaks or bursts*.

In the water system of the City of Boston, over 85 per cent. of the total number of leaks are in service pipes. As the greater number of services are of small diameter, the volume escaping in each leak is small, but on the other hand, because of their small volume, such leaks are less noticeable and are likely to continue for some time before being discovered; thus the total leakage is larger than that from main pipe breaks or bursts.

Next in the number of leaks are those in main pipe joints. These also vary in volume, but, as a rule, they are not large.

Lastly are the big leaks that are spoken of as breaks. Fortunately they do not occur frequently, but they are ever imminent, and our defensive system must be shaped to handle them at their worst.

In the old days, service and main pipe leaks were quickly discovered and easily located. The water usually came to the surface of the street directly over the leak, but since the use of hard pavement and the burial of wires, the location of a leak is a more or less difficult matter.

The escaping water is baffled in its attempt to come to the surface by the concrete base of the pavement, and it wanders about following a course of least resistance. Sometimes it leaks into the telephone or electric conduits and runs along with the wires from manhole to manhole. Sometimes it follows one of the various services — water — telephone — or electric — into a cellar; or it works its way through the foundation wall. Sometimes it finds its way into a sewer or a house drain. In the case of either of the two former courses, we hear from it shortly. But if it enters a sewer the

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chance of discovery is remote, unless the noise of the leak is heard and complained of by some householder, or the pressure drops to a point where the consumer is inconvenienced.

There are various devices that are said to be successful in locating leaks, but our experience with them in Boston has not been entirely so. They are supposed to convey to the ears the vibrations caused by the escape of the water from the pipe. In many cases where there is a cavity in the earth around the leak, it becomes filled with water and the noise of the leak is smothered. More frequently, however, the failure of the instrument to guide one to a leak is due to the many stray vibrations or noises that it picks up and conveys to the ear. To distinguish leak-noise from the babel of city sounds is quite an achievement. One may readily appreciate the difficulty if one considers the variety and number of noises to be heard day and night in a large city. The elevated railway — the subway — the automobile truck — machinery in deep basements — all intermingle their vibrations with that of the leak, and one of the surprising things about this confusion of sounds is the distance that some of them travel. Drawing of water within buildings and leaking stuffing boxes on underground valves tend to complicate matters.

Steel rods driven from the surface of the street to the main pipe are sometimes used to advantage to convey the sound of a leak to the ear. In some parts of the city it is rather dangerous to drive them underground as they are likely to encounter an electric or telephone wire, or a gas pipe.

We have had the best results with a small metal listening rod, with the aquaphone, which resembles a telephone receiver with a contact point, and with the common valve wrench. The last named is about as good as anything for outdoor testing. The aquaphone can be used to advantage on hydrants and by listening on service pipes within buildings.

The listening rod, usually made with a small ear knob on the end, is used anywhere that contact may be had with water fixtures. We get about as good results with one instrument as with another. The personal factor is very important. One must have good hearing and it must be educated to recognize a leak sound, if there is one.

Occasionally we are unable to get any assistance through sound. Water flows into a cellar or into some public service manhole, but there are no indications to be had by listening. Possibly there are three or more water mains in the street, and the structure entered by water may be so situated as to receive leakage from two or possibly three streets. In such a case, we start a process of elimination by shutting off one main after another in one street, and repeating the same operation in another street, until we note a cessation of the leak flow during the shutdown of one of the mains. Because of business and domestic inconvenience caused by shutting off the main supply during the daytime, this work is usually done at night.

The mere closing of the gate valves is often not sufficient to stop the leakage, especially not if it is small. Back-flows from large buildings, the

supplies to which are unchecked, leakage through the controlling main gate valves, and locked-in pressure will cause the leakage from the main to continue indefinitely. To get an absolute test, it is necessary to empty each main by means of a blow-off or a hydrant, or, if neither is attached to the main under test, to insert a large-sized tap — say 1½-in. — and connect it with some nearby sewer manhole.

Having singled out the leaky main and receiving no guidance from sounding devices as to the exact location of the leak, there is nothing to be done except to dig. Practical knowledge of underground conditions and the mechanical make-up of the main may help one in selecting a place to dig. Having exposed the pipe, but not the leak, conditions may be observed that will indicate the direction and proximity of the leak. The soil may be wet, there may be a flow from a certain direction, tunnelling and probing with a bar may be resorted to, listening on the main pipe through anything metallic, even a shovel or bar; if the main is shut off, noting the length of time required for the leakage to make its appearance in the trench after the water is turned on, etc. More holes than one may be necessary, but eventually the persistency and instinct for that sort of thing, possessed by all good water-works men, will win out, and the leak will be located. All this may seem a long, tedious operation, but at intervals it has to be gone through in every large city because of underground conditions.

Hydrant-waste leaks are not uncommon, now that hydrants are used as a means of public convenience rather than for fire protection. The operator may not close the valve tightly enough to prevent a small flow of water into the barrel and out through the waste. If the waste is not connected with the sewer, water may find its way into basements or cellars and result in complaints or claims for damages.

Stuffing-box leaks are of frequent occurrence where the valves are old, and are operated periodically, as they should be. The packing becomes hard, dry and lifeless, and, when the gate stem is turned, the water works its way out along the stem. The average valve box is so small as to prevent taking up the gland bolts, and digging has to be resorted to, unless it is possible to stop the leak temporarily by opening up the valve "hard," or striking the gland with the gate wrench. A slight jar of the gland sometimes causes the packing to readjust itself sufficiently to stop the leak, but it is merely a makeshift, and the gate should be properly repacked. Leaks in stuffing boxes sometimes continue for long periods before discovery.

A very serious leak, so far as conservation of the supply is concerned, is through an open blow-off gate. Blow-off gates, of course, should be kept closed except when used to empty or flush out a pipe, but once in a while a careless employee will open one by mistake, and it is only through strict attention to pumpage or Venturi meter records, or possibly through a drop in the gage pressure, that it is noticed.

Leaks in submarine pipes are observed only by vigilance. Constant attention to pressure gages, test cocks, and meters is required to detect

a loss of water. Patrolling the lines in boats is of value, as, in the event of a leak, bubbles may be observed coming to the surface. The introduction into the main of compressed air will locate a leak in a submarine pipe. The discovery and location of the leak is a much easier matter than its repair. The necessity for employing a diver and tide and weather delays make the repair of a leak under water a slow and expensive job.

The causes of leaks, so far as Boston is concerned, are many and varied. The outstanding one is settlement. With the exception of a few hills, Boston, many years ago, was under water. Later large areas of shallow water were drained off and filled in, leaving Boston as it is today with a soil of unstable quality. An excavation made almost anywhere in the city will reveal layers of various material,—oyster shells, silt, peat, loose gravel or quicksand, salt marsh, blue and yellow clays, rubbish, etc. Such an environment is none too good for a water pipe.

There is not only the chemical action from a soil made highly acid or alkaline by the decomposition of such materials, but there is the movement due to the continual readjustment of the materials of different density, resulting, for instance, from an excavation made for the foundation of a building, or the construction of a sewer or subway. In such work water, sand, and other loose and dissolved material are withdrawn from their places. The removal may extend for quite a distance in all directions. As a consequence, a replacement of the extracted material takes place with an attendant movement of the earth, both vertical and horizontal, which is reflected to a more or less great degree in the water pipes by straining and pulling and finally by leakage.

That soil of a "peaty" or "silty" character, which may be found in a considerable part of Boston, also is very susceptible to vibration caused by the passage of heavily loaded trucks and surface, elevated and subway cars; as a consequence, many leaks occur in it. It is in the sections of Boston where earth of this character is prevalent that our comforting friends, the earthquake specialists, tell us the effect of a quake will be most disastrous.

Electrolysis is a frequent cause of leaks, especially so in certain sections where underground electrical conditions are favorable for such action. That same soil which was once the bed of the sea and its inlets, is also a contributing factor to the destructive action of electrolysis. A salt-impregnated soil is very inviting to stray electric currents, and, where it is almost blended into the iron or lead water pipe which it surrounds, a current of electricity flowing along that pipe is inclined to leave it and to use that soil for a path. It is at the point of this exit that the damage is done. Many cases of disintegrated water pipes that we have hitherto ascribed to chemical action of the soil may be entirely electric or, at any rate, electrochemical.

Ashes, of which much of the filled-in areas of Boston is composed, are detrimental to both iron and lead and constitute the indirect cause of many leaks, especially in lead pipes.

Poor workmanship contributes to many leaks. In the case of a main pipe line, it may be that the joints were improperly made, the pipes improperly blocked or supported, curves not properly braced, backfilling not properly placed and tamped, the pipe allowed to rest on hard and rigid bearings, a cap placed on an end without a bead and not braced or strapped with some durable material. The casting may not have been handled carefully during transportation from the foundry to the pipe line. The weakness may have originated in the foundry where the mechanics and chemistry of pipe-making may not have been up to the required standard, etc.

In the case of a service pipe, the material may not have been selected with reference to the conditions under which the pipe was laid and used. In Boston we use lead pipe because of the corrosive effect of the soil on wrought iron or steel and the rust-forming tendencies of water in pipes of these materials. In some cities and towns lead cannot be used because the water will dissolve it; in other communities iron pipe may be used without any danger of clogging by rust; in other places the water is so acid that it is not safe to pass it through copper or brass pipes.

Leaks result in service pipes that are not properly laid. The couplings may not be made up tightly. Washers are sometimes not used where they should be, and, when used, they are not of the proper quality and workmanship; a poor washer occasionally will cause a serious leak. Starting with a very small stream, the swirling sand of the fill around the pipe will wear away the brass or lead and a large leak will be developed. The water will wash away the filling from under the pipe which will be borne down by the weight of the street above; it will finally give way under the strain, and a broken pipe or corporation cock will result. The evolution of a small washer leak, as outlined in the foregoing, has been frequently observed by the writer.

Threads cut too deeply into scantily stocked iron pipe often result in leaks and breaks at the coupling.

Lack of support under service pipes at critical points will develop into leaks. There are two points particularly: one at the main, the other at the foundation wall of the building.

Lead pipe of poor quality and workmanship will soon be heard from. The lead should be prime metal and not remelted scrap, and the walls should be of uniform thickness. More than ever is strong, tenacious lead pipe required since the advent of quick-closing fixtures, flushometers, etc., now used generally in plumbing. The water hammer created by these fixtures will frequently split a large-sized lead pipe, if there is any weakness in its material or fabrication.

Solder joints not made with the requisite skill and care are likely to leak.

The flanging and flaring required in the various patent couplings used more or less by water works, unless done carefully and with precision, will develop into a defective joint.

Joints made by inserting the tail piece of a brass coupling into the flared-out end of a lead pipe and by filling with solder the space around it in the cup thus made, are so dense and hard, in comparison with the lead pipe just beyond, that, if any settlement occurs where these couplings are attached to the corporation or curb cocks, there will be an opening in the lead pipe just beyond the end of the tail piece. This is caused by the abrupt change from a hard mass of brass and solder to soft lead. There is a hinge effect at this point, and, when settlement causes the line of pipe to sag and the limit of resistance is passed, the lead will open, and the water will come out.

Another cause of leaks, although it may be indirect, is the underground construction work continually carried on by the gas and electric light and power companies, the telephone, telegraph, pneumatic tube and steam-heating corporations. It appears to be everlasting. In the narrow streets of Boston, they are burrowing here and there, trying to find a space in which to lay or enlarge a conduit or manhole. For many years their work was largely above the water pipes; then our trouble was to keep them from covering us. Later they came down to our grade; then our trouble was to keep them from blocking the horizontal approach to our mains. Now they are below our grade, and our trouble is to see that our mains are supported while they are excavating below them and to be sure that permanent supports are placed under them before the backfilling takes place. No matter how carefully work of this kind is carried on, the disturbance to our pipes is such that sooner or later we are required to repair leaks or breaks that occur while the pipes are readjusting themselves to the new conditions.

The remedies for the many kinds of leaks mentioned in the foregoing are suggested in their causes. It will require a long time, however, to apply effective remedies throughout the system, and, by the time that all present known weak spots have been strengthened or eliminated, a new set will have made its appearance, so that, as stated before in this paper, we shall have leaks, which, "like the poor will be with us always."

We stand in need of a material for service pipes that will possess all the desirable and none of the undesirable qualities of the various materials now used. In a general way, it should have ample strength to withstand all kinds of stresses and strains, both internal and external. It should not be subject to corrosion from the water it carries or the soil in which it lies. It should not transmit any harmful or poisonous properties to the water. It should be reasonable in price and plentiful in supply. It should not cost too much to lay and connect.

In an improved main pipe, I think we should look for a material that will combine the strength of steel with the durability of cast iron, that will be rust-resisting, have a permanently smooth interior, and have a water-tight joint of simple mechanical design that will not require packing that has to be cooked or calked.

Some improvement in materials, fittings, and workmanship is called

for to counteract the adverse conditions that produce leaks and to reduce the amount paid out in settlement of claims for damages caused by the water escaping through leaks.

Litigation.

Litigation is increasing steadily. It is epidemic. One person learns from another what to do and how to do it. The courts are choked with civil actions. Lawyers are multiplying in number. The public is getting keener and keener for the dollar. The desire for easy money is gaining strength. So, when some people think they have the slightest opportunity to secure damages they lose no time in starting action. That they are not always successful does not deter them. The City of Boston employs a force of twelve lawyers to combat the claims and suits for alleged damages. There is also a Committee of Claims composed of members of the City Council who consider and pass on claims under $500. The Police Department does some preliminary investigation in all claims under $500.

The Water Service has one man who devotes his entire time to investigating claims and examining all premises where water has entered or where there is any possible chance that a claim will be made. The work of this man is valuable inasmuch as he is on the ground while the matter is fresh and gets his facts at first hand and by direct observation. Shortly after a leak or break of any consequence has occurred this man is notified, and he makes a personal examination of the premises affected and lists all property that may be involved in a future claim. This is a check on the inflation of an inventory of damaged goods presented by the plaintiff at a trial held perhaps several years later when memories are dim and important witnesses are absent or dead.

The total amount paid by the Water Service of Boston in settlement of claims for damages and awards by judge and jury during the last six years was $100 220.44 or an average of $16 703.40 each year.

To give an example of the amount of unwarranted damages asked for by claimants, the records of the city of Boston, for a certain period, show a total of $470 300 *ad damnum* or amount sued for, and a total of $26 715 actually awarded. That is equivalent to a 5.7 per cent. recovery or about 1/18 the amount which claimants considered they were entitled to.

The amount of money which this litigation runs into yearly emphasizes the necessity for preventing, as far as possible, the occurrence of leaks and breaks and of minimizing the damage resulting from the same by quick and efficient action in stopping the flow once started, by energetic work in removing water from the flooded premises, by performing salvage work and assisting within proper limits in getting the interrupted business or service back on a working basis as quickly as possible and by effectively opposing any attempt on the part of the plaintiff to collect unreasonable or unwarranted damages.

The Boston Department protects itself to a certain extent by stipulating in an application made by an owner for a fire pipe that the City will not be liable for damage resulting from a leak or break in the pipe. The legal basis for a stipulation of this sort is the fact that no revenue is derived from water furnished for fire protection and that the extinguishing of fires is a governmental function. The application has the force of a contract, and the immunity of the City has been upheld by the courts.

Likewise, damage from a broken water main, if the main is used exclusively to furnish water for fire protection, cannot be recovered for the same reason, namely, that fire extinguishing is a governmental function.

While a hydrant is supposedly a fire-fighting fixture, it is usually so involved with the business of supplying water for domestic purposes, for which a revenue is received, that the courts do not free it from liability. A hydrant, unless it is connected with a strictly high pressure fire service main, is usually connected with a main that supplies water for domestic purposes. It has also become the source of supply for contractors engaged in construction work and thus becomes a medium of revenue.

Damages due to leaking or defective service pipes, or to the mains that supply them, are recoverable under certain conditions because of the revenue factor.

The following excerpts and citations from records of Massachusetts court cases will give an idea as to the legal liability of municipally or privately owned water systems for damages or breach of contract: —

City's Liability.

The City of Boston having voluntarily entered into a commercial enterprise for the purpose of supplying its inhabitants with water is to be regarded as a private corporation, and it is liable for personal injuries or property damage caused by reason of the negligence of its officers, agents, or employees, engaged in the construction, operation, or maintenance of its system of water works.

The obligation of the City is, *not to insure* the inhabitants against injury or damages, but it *must exercise reasonable care and vigilance* in the construction and operation of its works.

McLaughlin v. *City of Boston.* Pipe frozen by removal of ordinary protection by one Barry in laying a sewer. Only one foot of cover over water pipe.

Liability of City for Negligence of Water Department.

A city in carrying on its water department is engaged in a work voluntarily undertaken by it, partly commercial in character, and for which it receives pay from those making use of the water, and is *quoad hoc* (to this extent) to be regarded as a private corporation. The city is thus liable for personal injuries caused by the negligence of its officers, agents, or employees, while engaged in the construction and operation of its system of water works. *White* v. *Board of Health*, L. R. 10 Q. B. 219. *Scott* v. *Manchester*, 1 H. & N. 59. *Wilson* v. *Underhill*, 108 Mass. 361. *Fox* v. *Chelsea*, 171 Mass. 297. *Lynch* v. *Springfield*, 174 Mass. 430.

Municipality Liable Like Private Corporation in Constructing and Maintaining Water Supply System.

Where a city or town has been authorized by a special statute to construct and receive profits from a water supply system, and has voluntarily accepted the same, it is just as liable as is a private corporation or an individual for negligence in the manner of construction of its works by which injury or damage is caused to person or property. *Hand* v. *Brookline*, 126 Mass. 324.

A city is liable to travellers who are injured by reason of the negligent laying and maintaining of pipes or hydrants in the streets or highway. *Hand* v. *Brookline*, 126 Mass. 324.

City Liable on Same Grounds as Private Corporation.

A city voluntarily maintaining a water system and receiving pay from the takers of water is engaged in a commercial business and with reference to the distribution of water is to be regarded as a private corporation. It is liable, therefore, for personal injuries caused by the negligence of its officers, agents, or employees, while engaged in the construction and operation of its system of water works. *White* v. *Board of Health*, L. R. 10 Q. B. 219. *Scott* v. *Manchester*, 1 H. & N. 59. *Wilson* v. *Underhill*, 108 Mass. 361. *McAvoy* v. *New York*, 54 How. Pr. 245. *Bailey* v. *New York*, 3 Hill, 531. *Estberg, etc.* v. *Portland*, 34 Oregon, 282.

City Liable Only for Reasonable Care and Vigilance in Construction and Operation of Works.

If due diligence is used in laying and maintaining the pipes no one can be held liable for their breaking. Nor is the liability of the city such as to insure the citizens against personal injury or damage to his property. The city is liable when it fails to exercise reasonable care and vigilance in the construction and operation of its works. *Ring* v. *Cohoes*, 77 N. Y. 83. *Hunt* v. *New York*, 109 N. Y. 134. *Jenney* v. *Brooklyn*, 120 N. Y. 164. *Terry* v. *New York*, 8 BOSW. 504. *Green* v. *Chelsea, etc.* 70 L. T. NS. 547.

Liable for Negligence.

A city may be held liable for negligence in the construction of water works or the laying of water pipes. *Lynch* v. *Springfield*, 174 Mass. 340. *Fox* v. *Chelsea*, 171 Mass. 297. *Stoddard* v. *Winchester*, 157 Mass. 567.

Liability of a Water Company for Accident Due to Negligent Construction or Improper Location of Water Fixtures and for Damage Resulting from the Bursting of an Underground Pipe.

When a water company complies strictly with the statutes or ordinances regulating its fixtures and permanent apparatus in the streets, and keeps such fixtures in good repair, it is not liable for accidents to passers-by; but the company is liable for any accident due to the negligent construction or improper location of such fixtures. So also as to underground pipes, the company cannot be held liable for damage resulting from the bursting or leaking thereof, unless the pipe was negligently constructed or laid or the company has negligently failed to make repairs, the necessity of which has been brought to its notice; but in case of such negligence the company, of course, is liable.

Actions.

The complaint in an action based on the negligence of a water company must show the existence of such negligence, and that it was the proximate cause of the injury complained of. Plaintiff has the burden of proof as to matters necessary to his recovery, and, if there is a substantial variance between his complaint and the proof adduced in support thereof, he cannot recover. The usual rules of practice govern as to the effect of evidence and the propriety of instruction. When the facts are controverted, the question of defendant's negligence is for the jury, who must also decide whether such negligence was the cause of the injury, or, when the action is based on contract, whether the alleged contract existed. Damages proportionate to the injury suffered by plaintiff should be awarded; but where the suit is by a municipal corporation, damages suffered by individuals by reason of the failure to furnish the stipulated quantity of water cannot be taken into account.

Leak in Water Pipe Undermining the Highway.

Hand v. *Brookline*, 126 Mass. 324. The plaintiff, while travelling with due care in a wagon upon the highway, was injured by reason of his horse suddenly breaking through the surface of the highway. The declaration contained two counts.

1. Under the statutes alleging a defect in the way which the town was bound to keep in repair.

2. At common law for neglect in construction of water pipes whereby the water escaped and undermined and washed away the earth under the highway.

The plaintiff and court agreed that the first count could not be maintained and went to the jury on the second count. The jury found a verdict for the plaintiff.

Held, that on the evidence he could not recover on the first count, but that he could on the second.

Inasmuch as the evidence was conflicting as to the negligence on the defendant's part as to the original construction of the water pipe, the case was rightly submitted to the jury.

Judge Gray stated in the case:

"The right of action against a city or town for a defect in a highway is, as has been repeatedly affirmed by this court created and limited by the statutes. Gen. Sts. C. 44, S. 22. But those statutes do not affect the common law liability of owners of aqueducts for damages caused by negligence in their construction. If the water works under the highway in Brookline had been constructed by an aqueduct corporation or by the City of Boston under authority of the Legislature, and for the purpose of supplying water at certain rates or rents, the corporation or the city would clearly be liable in an action like this; and the Town of Brookline is not the less liable for any injury resulting from a neglect in the construction of its water works because it happens to be also the town in which the highway is situated and which is bound by general statutes to keep the highway in repair."

Shut-off Box May be a Defect.

Redford v. *Woburn*, 176 Mass. 520. The plaintiff stumbled over a water shut-off box in the middle of a sidewalk and was injured. The box projected above the surrounding gravel $\frac{1}{8}$ in. on one side — $\frac{1}{4}$ in. on another side — and $1\frac{1}{2}$ in. on a third side.

Held, that the jury might be warranted in finding the shut-off box to be a defect.

Judge Morton said: "The fact that the shut-off was the usual contrivance used in cities for the purpose for which it was placed in the sidewalk would not justify the defendant in maintaining it in such a condition as to render the highway defective and unsafe.

We do not think it could be ruled as a matter of law that the jury was not warranted in finding that a shut-off box in the middle of a sidewalk much used for foot travel projecting on one side an inch and a quarter above the surrounding gravel, did not constitute a defect. Whether such an object was liable to cause travellers, while in the exercise of due care, to stumble and fall, or to turn or sprain the ankle as we infer the plaintiff did, and whether the defendant exercised reasonable care in suffering the box and sidewalk to remain in the condition in which they were in, seems to us questions for the jury."

Judge Lathrop in the case of *O'Brien* v. *Woburn*, 184 Mass. 598, said: "The plaintiff stumbled over a water shut-off in the sidewalk of Green Street in the defendant city, fell and sustained personal injuries for which she seeks to recover damages in this action. The shut-off was in a travelled part of the sidewalk and extended above the surface thereof, according to some of the witnesses from a half inch on one side to an inch and a quarter on the other side, and according to eye witnesses it so extended an inch and a half on one side and two inches on the other. It is not controverted that it was competent for the jury to find that this was a defect."

Liability of a Town for Damage to Plaintiff's Property Caused by an Overflow from a Standpipe Maintained by the Defendant.

Kelly v. *Winthrop*, 219 Mass. 471. A town which maintains a standpipe that was built and is operated, not only for protection against fire, but also "to equalize the pressure in general for the domestic service" supplied by the town as a commercial enterprise for its own corporate benefit, is required in the maintenance and operation of the standpipe to use reasonable care to avoid injury to adjoining private property.

If a town maintains and operates a standpipe in part for the distribution of water as a corporate commercial enterprise, its liability for injury to adjoining private property, by reason of negligence in the maintenance or operation of the standpipe, is not affected by the fact that the water used in the standpipe is obtained from the Metropolitan System.

In an action against a town for damage to the plaintiff's property, caused by the overflow of a standpipe maintained and operated by the defendant in part for the distribution of water as a corporate commercial enterprise, it appeared that before the time of damage no overflow from the standpipe had occurred, that the overflow in question was due to the clogging of the regulating valves of the conduit of the Metropolitan Water System from which the defendant obtained the water that was used in the standpipe, that the defendant had no control over this valve, but that it had knowledge that if foreign substances, floating in the water, passed into the valve, it would cease to work automatically and would leak, causing the standpipe to overflow, and that, if an overflow pipe had been provided, as was possible, the water would have been discharged on the defendant's own land and the plaintiff's property would not have been damaged.

Held, that the jury was warranted in finding that the defendant reasonably ought to have anticipated and guarded against the condition that

occurred and that its failure to do so was negligence for the consequences of which it was liable to the plaintiff.

Liability of Town for Failure to Supply Water Due to a Leak in Standpipe.

In the case of *Watson* v. *Needham*, 161 Mass. 404, it appeared at the trial of an action for breach of contract by a town to furnish a person with water for use in a boiler to make steam to heat his greenhouse that, in the regulations which were made part of the contract, the right was expressly reserved to shut off the water in all cases when it becomes necessary to make extensions or repairs and whenever the commissioners deemed it expedient.

There was evidence tending to show that the damage to the plaintiff was not caused by the exercise of this reserved right, but by a leak which remained undiscovered until after the standpipe had been emptied and there was no longer any pressure in the service pipes, and the inference was warranted that due diligence was not used to discover such leaks quickly, to shut off the flow of water to the place of the leak and to start pumping engines so as to prevent the standpipe from being emptied.

Held, that the court might properly find a breach of contract.

Liability of City for Destruction of Plants in a Greenhouse Due to the Freezing of a Water Supply Pipe.

In *Stock* v. *Boston*, 149 Mass. 410, it appears that the city, under contract with the owner of a greenhouse to supply him with water for steam heating and for his plants, in constructing a sewer in an adjacent street, caused the supply pipe to be uncovered and negligently exposed to the cold so that the water in the pipe was frozen and his supply cut off. The owner could not by the use of reasonable diligence obtain a supply of water or heat from other sources, and the plants were destroyed.

Held, that the exposure of the water pipe was the proximate cause of the injury; and that the city was liable to such owner in tort for such damage, even if he might recover the same damages in an action upon the contract.

In this same case Judge Morton said: "The defendant contends that the damages suffered by the plaintiff were too remote. The damage was caused, because the plaintiff, after the water was cut off, was unable to furnish water to his plants and to supply his boiler with water so as to heat the greenhouse."

In *Derry* v. *Flitner*, 118 Mass. 131, it is said: "One who commits a tortious act is liable for any injury which is the natural and probable consequence of his misconduct. He is liable not only for those injuries which are caused directly and immediately by his act, but also for such consequential injuries as, according to the common experience of men, are likely to result from his act. And he is not exonerated from liability by the fact that intervening events or agencies contribute to the injury. The true inquiry is whether the injury sustained was such as, according to common experience and the usual course of events, might reasonably be anticipated."

In the case at bar the natural consequences of the tortious acts of the defendant, in leaving the pipe exposed, were that the water in it froze, the supply of the plaintiff was cut off, his means of furnishing water to the plants and heat to his boiler were destroyed and his plants were killed. The jury have found that this happened without any negligence on the part of the plaintiff, and as he could not by the use of reasonable diligence obtain a supply of water or heat from other sources.

The case of *Metallic Compression Casting Company* v. *Fitchburg Rail-*

road, 109 Mass. 277, is similar to the case before us. There the defendant negligently ran a train over a line of hose belonging to a third party, which the plaintiff was using to extinguish a fire in its factory. It was held that the severing of the hose was the proximate cause of the destruction of the building and that the defendant was liable for its value. The instructions in this case were in accordance with the principles we have stated and were correct.

It is quite evident from the foregoing legal citations that it is good economic policy for a water department or company, in Massachusetts at least, to do all in its power to bring the condition of its reservoirs, dams, standpipes, pipe lines, service pipes, gates, hydrants, and other fixtures and fittings to a high degree of safety, soundness, and efficiency, and, by constant vigilance and attention, to maintain them as such and not to leave itself open to the charge of negligence or lack of diligence in avoiding damage or breach of contract. It should be an ever present thought in the minds of those responsible that a leak or a break, large or small, a defective fixture or fitting, and a neglected weak spot or danger spot are potential court judgments requiring the payment of sums of money of varying amount.

DISCUSSION.

DAVID A. HEFFERNAN.* I should like to tell of an experience that we had in Milton a few months ago.

A foreman in a manufacturing plant in the Lower Mills section of the town noticed some water coming through a stone abutment of a bridge across the Neponset River. His attention had been drawn to this point by children looking over the fence to watch a school of alewives. The fish had gathered in the river at a point just below where clear water was coming through the wall. Passing this point, and running up the hill some distance, were two 24-in. Metropolitan mains and one of our 8-in. pipes. We went over the three lines very carefully with the Geophone and determined the leak to be in one of the 24-in. Metropolitan mains about 100 ft. from the bridge.

The two 24-in. lines ran side by side up the hill from the river for a distance of about 2 000 ft. You can understand, therefore, that it took some time for this column of water to empty from the pipe so that it was a few days before we were absolutely certain which of the two lines had been leaking.

However, the tests made justified the location of the leak as shown by the Geophone, and, when excavation was made at the point indicated, it was found that a wood insulating joint had blown out, permitting the loss of about 200 000 g.p.d. The waste of water made a subterranean passage alongside of the pipe down to the river almost large enough for a man to crawl through.

*Superintendent, Milton Water Works, Milton, Mass.

The excavation was made on Friday, appropriately enough, inasmuch as the fish were responsible for the leak being discovered. It is of interest to note that following the closing of gates, which stopped the waste of water, the fish disappeared for places unknown, which may or may not prove that the desire for pure water had led the fish to a point where the water was wasting through the wall.

PERCY R. SANDERS.* May I ask what the general attitude of water-works men in New England is in regard to hot-water tanks that collapse as a result of shutting off a leaky main. Some time ago a leak appeared in a main under the Daniel Webster Highway. Our men notified the property owners and tenants of neighboring houses before shutting off the water. Nevertheless one tank collapsed. The owner presented a bill for a new tank and our Board paid it. I have always taken the ground that in a case like this the city was not liable.

DAVID A. HEFFERNAN. A short time ago, when one of our hydrants on a 10-in. main supplying the east section of the town was knocked over by an automobile, three pressure boilers on branches off the main line beyond the hydrant mentioned collapsed. In each of the three cases the installation was up-to-date with the required vacuum and relief valves. In spite of this equipment the vacuum valves did not function and, when we visited the houses, each of the boilers was about as flat as the proverbial pancake. In each of these houses was the wife of the owner. Of course, she was quite excited and shut the water off in the cellar.

When we permitted the water to flow under pressure into the boiler, the boiler, in each case, resumed its normal shape with the exception of a few wrinkles which did not come out entirely.

GEORGE H. FINNERAN. In my search for legal information I have been unable to get a statement or ruling on collapsed boilers. So far as I know, the City of Boston never paid a claim for a collapsed boiler until a few years ago. Incorporated in the rules and regulations governing the sale and use of water, is a stipulation that the City will not be responsible for the collapse of a boiler due to shutting off the water supply and that it is incumbent upon the water taker to guard against collapse of a boiler and other injuries that may result from lack of water, as the water is likely to be shut off at any time without notice. We have always reserved the right to shut off without notice, if necessary, but we always try to give notice and to advise as to the precautions to be taken against collapse, etc. This notice is in printed form and is left at every house affected by the shutdown. Notwithstanding, settlements have been made during the last five or six years in claims for collapsed boilers. Why, or upon what legal grounds, I am unable to say. There should be a test case, the result of which would serve as a guide in the matter. The regulations that we make, and which the water taker accepts when he applies for water, seem to have the force of a contract and therefore give to us a sense of security, but this is broken

*Superintendent of Water Works, Concord, N. H.

down when the court occasionally will hand down a decision holding us liable in a case where the liability seemed to be very remote.

Among the citations in my paper there is reference to a case where, because of a frozen pipe, the water supply to a greenhouse stopped. The water was used in the greenhouse to supply heat and nourishment to the plants. The pipe froze because it was exposed by the operations of a contractor engaged in building a sewer. The contractor's excavation left the pipe with only one foot of cover during freezing weather. When the water supply to the greenhouse stopped, the heat stopped, and the plants died of cold. The judge held the City of Boston liable for the destruction of the plants because of a frozen pipe due to the operations of a sewer contractor. Here is a case where cause and effect are far apart and where an apparently blameless third party is selected to pay the bill.

Another case cited is where a hose was laid across a railroad track in order to put out a fire. The Boston and Maine Railroad Company ran a train of cars over the hose and cut it, rendering it useless for putting out the fire. The man who owned the burned building recovered from the Boston and Maine Railroad Company for the destruction of his building due, as he claimed, to the cutting of the hose. As a further complication in this case, the hose was owned by a third party.

The decisions in these cases show that, while sometimes the cause seems quite remote, yet legally the city or corporation does not escape liability.

LOG PIPE FROM BOSTON'S EARLY WATER WORKS.

BY CHARLES W. SHERMAN.*

[*Received October 7, 1927.*]

The accompanying photograph shows one of the 4-in. log pipes of the "Jamaica Pond Aqueduct" through which the water supply of a part of Boston was furnished during the first half of the nineteenth century. This pipe was taken up in 1927, in Park Square, and when taken from the ground was in an excellent state of preservation. The logs were from 8 to 12 ft. in length, and the joints were made by mortise and tenon, as the picture shows. The tenon end in the photograph was injured in removing the pipe from the ground.

FOUR-INCH LOG PIPE, ORIGINALLY PART OF THE "JAMAICA POND AQUEDUCT."

The only authentic information about this water system which I have found is quoted below. On the basis of this description it is probably safe to assume that the pipe here illustrated is at least 100 years old, and possibly as much as 125 years. The statement is as follows:

JAMAICA POND AQUEDUCT.

By Dr. N. B. Shurtleff; quoted in Bradlee's History of the (Boston) Water Works, 1868, page 2.

"On the 27th. of February, 1795, Governor Samual Adams approved an Act of the General Court whereby Luther Eames, Nathan Bond and

*Of Metcalf and Eddy, Consulting Engineers, Boston, Mass.

William Page, and their Associates, were vested with corporate powers for the management and direction of the business, as a Company, of bringing fresh water into the town of Boston by subterraneous pipes; and, by a subsequent Act passed on the 10th. of June, 1796, this Corporation was empowered to assume the appellation of 'THE AQUEDUCT CORPORATION.'

"The Corporation was authorized 'to bring from any part of the town of Roxbury into the town of Boston, and into any street in the same town, all such fresh water as they, the said Luther Eames, Nathan Bond and William Page, and their associates, or any, or either of them, in their private and natural capacities "then had or hereafter should" have a right to dispose of or to convey from the springs or sources thereof.' The act gave power also to open the ground in any of the streets or highwaysin Roxbury and Boston as should be required for the sinking of the water pipes, but with very prudent provisions, which prevented the aqueduct from becoming a nuisance, or impairing any right of the town of Roxbury or any of its inhabitants in and to the waters of Jamaica Pond.

"The Corporation could hold only thirty-three thousand dollars in real estate, and the water works were to be divided into one hundred shares.

"The price of water was to be regulated by the General Court, the towns of Boston and Roxbury were to have the privilege of hydrants for extinguishing fires, and the first meeting was to be called by Hon. James Sullivan, upon the proper application of the persons named in the act. On the 22d of June, 1803, an Additional Act was passed to facilitate the operations of the Corporation.

"The Capital of this Company, so far as can be ascertained, was about one hundred and thirty thousand dollars, or about thirteen hundred dollars to a share, which became much depreciated in value.

"No dividends were made during the first ten years after the commencement of the works, and subsequently the average of the dividends for thirty years amounted to a fraction less than four per cent a year. When the Aqueduct was in its greatest prosperity it supplied about fifteen hundred houses with water, chiefly at the South End, and in the neighborhood of Summer and Essex, and of Pleasant and Charles Streets.

"The water was brought from Jamacia Pond in Roxbury through four main pipes of pitch-pine logs, two of four inches bore, and two of three inches, the lateral pipes having a bore of one and a half inch. The lineal extent of the water pipes in Boston was about fifteen miles, and they reached north as far as Franklin Street, and branched off easterly through Harrison Avenue into Congress Street nearly to State Street, and to Broad Street. They also branched off westerly through Pleasant and Charles Streets, extending as far as the Massachusetts General Hospital, which was supplied with Jamaica Pond water."

FIVE YEARS OF RAPID SAND FILTRATION AT CAMBRIDGE, MASS.

BY MELVILLE C. WHIPPLE* AND HAROLD C. CHANDLER.†

[*Read September 15, 1927.*]

Since April, 1775, the people of Middlesex have looked upon that month as one providing unusual and unexpected happenings. So it was, that on the 26th of April, 1923, the astonished citizens of Cambridge, County of Middlesex, awoke to the realization of striking changes in their public water supply. Drinking glasses no longer conveyed the odor of the bog, and baths failed to reflect the color of the swamp. The transformation resulted from turning into service on the previous day the new 14 million gal. water purification works. This new link in the Cambridge Water Works system is in series with the old sources of supply on the one hand, and the old pumping station, service reservoir and distribution system on the other.

The story of the operation and performance of this plant, at the time of its opening the largest rapid sand filter plant in New England and at present the only one municipally operated in the State of Massachusetts, has been thought to be worthy of recital. Some of its problems have been pioneer ones in this part of the country; they may serve to furnish guidance for other similar plants that are bound to follow.

A complete description of the works will not be given in this paper. Details of construction and of various special features have already been presented to the Association in a paper by Col. George A. Johnson,[1] the designing engineer, and by his associates.

Water Sources.

A word as to water sources is needed in order to convey some understanding of the quality of the raw product that is subjected to refinement and purification.

The main supply is derived from the Stony Brook catchment area from which water is conveyed by gravity to the purification works through 7.5 miles of pipe line and conduit. The catchment area covers 23.6 sq. miles and contains two impounding reservoirs, Hobbs Brook, having a storage capacity of 3 000 million gal. and a drainage area of 6.5 sq. miles, and Stony Brook, having a storage of 400 million gal. and a drainage area of 17.1 sq. miles. All the water passes through the Stony Brook reservoir, Hobbs Brook being fed into Stony Brook by open channel when the latter does

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†Chemist, Water Purification Works.

not furnish an adequate supply. The Hobbs Brook reservoir is very large in relation to its drainage area, but in recent years has filled each season. Stony Brook reservoir is not large enough to retain the flood flows and since 1922 has discharged an average of 2 500 million gal. to the Charles River; this is the equivalent of nearly 200 days consumption in the city.

In addition to the above mentioned sources there is Fresh Pond in Cambridge, on the shores of which the purification works have been built. This furnishes a reserve supply from which water is pumped and mixed with Stony Brook water when the latter does not supply the needs of the filtration plant. Fresh Pond has a drainage area of about one sq. mile. It fills each season from the surplus water that is brought by conduit from the Stony Brook catchment area. Diversion takes place at a weir chamber about one-half mile from the Fresh Pond intake at the plant. Pond water is pumped when the Stony Brook supply is inadequate; it mixes with the latter at the inlet valve chamber of the plant. The practice is to carry Stony Brook reservoir at a low level in the dry months in order to retain the run-off from heavy rains. During the year ending March 31, 1927, it was necessary to pump 775 million gal. from Fresh Pond; 4 090 million gal. were delivered to the purification works by gravity.

Quality of the Raw Water.

Stony Brook. The quality of the raw water from Stony Brook is characteristic of that of the impounded surface waters of New England. Numerous swamps on the catchment area contribute a considerable organic content and color. Geological structures are such that turbidity is very low and the hardness moderate. The upper waters of Hobbs Brook often have a color of 100 p.p.m.; after long storage and passage through the reservoir the color of the water discharged is only 30 to 40 p.p.m.

Stony Brook reservoir offers a shorter period within which improvement may take place, but the water of Stony Brook is less highly colored at its sources than is that of Hobbs Brook; consequently the two waters are comparable in organic content and color through many months of the year.

From the bacteriological viewpoint there is not a heavy burden of purification. During many months the number of bacteria will average less than 100 per c.c. at 37° and a few hundred at 20°, with a presumptive index for Bact. coli of less than 10 per 100 c.c. Under the worst conditions the 37° bacteria will average several hundred per c.c., the 20° bacteria a few thousand and the index for Bact. coli from 25 to 75 per 100 c.c.

Such fluctuations are within the realm of probability in water from an area containing a population of about 125 per sq. mile, to which must be added a considerable number of tourists and pleasure seekers. Attempts to enforce strict sanitary regulations, together with storage of the water, will not effectually prevent or remove the constant menace of contamina-

tion. Filtration of this water is justified on the ground of safeguarding its hygienic quality, as well as for other reasons.

The growth of microscopic organisms in Stony and Hobbs Brook reservoirs seldom reaches more than moderate proportions, and tastes and odors are faint. This is largely due to the exclusion of light by the natural color of the water, and in Stony Brook reservoir to the absence of areas of shallow flowage.

The impression must not be gained that the quality of the raw product delivered for purification is markedly uniform. Physical, chemical and bacterial constituents vary widely in the course of a year and the changes are sometimes "flashy" because of rapid flow through the Stony Brook basin. As an example, in the month of August, 1927, changes, very striking for the season, manifested themselves as a result of heavy rains. The quality of Stony Brook water became that of early spring and late fall rather than that of midsummer. Table I presents data that show the transformation.

TABLE I.

ANALYSES OF STONY BROOK WATER, ILLUSTRATING RAPID CHANGES IN QUALITY.

Date 1927.	Color p.p.m.	Alkalinity p.p.m.	CO_2 p.p.m.	pH.	Bacteria per c.c.		Presumptive Coli.		
					20°	37°	0.1	1.0	10.0
Aug. 8	40	15	3.5	6.75	80	90	0	0	+
Aug. 9	55	15	7.0	6.60	50	60	0	0	+
Aug. 12	53	16	6.0	6.65	200	130	0	0	+
Aug. 16	65	16	6.0	6.65	180	90	0	0	+

The greatest changes will be noted in the color, carbon dioxide and hydrogen ion concentration. The prolonged rains of fall and the melting snow of spring modify, also, the alkalinity and bacterial content.

Fresh Pond Water. Fresh Pond water, which makes up about 15 per cent. of the total water filtered, is different in many ways from that of Stony and Hobbs Brook reservoirs. Although the latter contribute annually a large volume to Fresh Pond, there is long storage in the pond, and it receives from its drainage area water lower in organic content and higher in mineral content. The differences between the two waters are apparent in Table II. Most striking are the lower color values, higher alkalinity, higher pH value, lower bacterial content and greater numbers of microscopic organisms in the pond water. Before construction of the purification works the physical and chemical properties of Stony Brook and Fresh Pond water were much alike. A typical analysis of Fresh Pond at that time is given on the last line of Table II. All Stony Brook water that was used then passed through Fresh Pond. The changes of recent years have been most interesting.

TABLE II.

AVERAGE ANALYSES OF RAW WATER SOURCES 1923 TO 1927.

Results are p.p.m., unless otherwise stated.

Sample.	Time of Collection.	Temp. F.°	Turb.	Color	Odor	Chlorides	Hard.	Alkal.	Incrust.	Iron	CO_2	pH	Nitrogen as				Oxygen consumed	Micro-Organisms S. U. per c.c.	Bacteria per c.c.		B-ct. coli. per 100 c.c.
													Free Ammon.	Nitrite	Nit-ate	Album. Ammon.			20°	37°	
Stony Brook	Spring	53	2	47	1v	5.5	28.0	13.5	14.5	.29	4.0	6.75	.010	.001	.33	.175	5.8	46	180	33	4
Stony Brook	Summer	69	2	40	2v	5.5	32.0	17.0	15.0	.21	3.5	6.95	.009	.002	.25	.200	4.7	198	170	70	7
Stony Brook	Fall	53	4	41	2v+1a	6.5	29.5	15.0	14.5	.30	2.5	7.05	.010	.001	.17	.209	5.6	773	210	85	3
Stony Brook	Winter	40	2	37	2v	6.0	30.5	12.0	18.5	.15	5.5	6.75	.050	.001	.37	.197	5.0	59	500	80	6
Fresh Pond	Spring	57	4	15	1v+1a	7.0	42.5	24.0	19.0	.16	1.0	7.35	.015	.005	.32	.213	2.7	830	160	4	0
Fresh Pond	Summer	71	3	14	2v+1M	7.5	42.0	25.5	16.5	.13	0	7.75	.010	.005	.38	.197	2.2	485	42	10	5
Fresh Pond	Fall	62	3	14	1v	8.0	40.5	26.5	14.0	.15	1.0	7.35	.051	.015	.18	.178	2.5	1 400	130	30	5
Fresh Pond	Winter	42	3	14	1v	7.5	43.0	27.5	15.5	.16	1.0	7.30	.038	.005	.34	.163	2.8	390	60	5	10
Fresh Pond prior to filtration	7–12–21	..	2	29	3v	7.0	28.0	16.5	11.5	.15	4.0	6.75	.002	.003	.30	.064	3.4	1 900	750	175	10

Purification Process at the Present Time.

A summary of the purification process at Cambridge may serve to visualize the general conduct of operations at the present time. The details of each step will then be considered separately.

Raw water enters the plant by gravity through a 42-in. cast-iron line that runs from the conduit weir chamber one-quarter of a mile distant. When it is necessary to augment the gravity supply, water is pumped from Fresh Pond through a 30-in. line that joins the 42-in. at an inlet valve chamber. This is 100 ft. from the coagulation basin.

Coagulating Chemicals. In the valve chamber there is a screening hopper and an F. B. Leopold dry-feed machine, hydraulically operated, for the addition of dry sodium aluminate. This chemical has been added continuously since December, 1926, in dosages varying from 0.15 to 0.50 grains per gal. Experience indicates that about 0.20 grain per gal., or 57 lbs. per million gal., is usually the optimum amount.

There is provision in the valve chamber for addition of soda ash, sodium carbonate, whenever the raw water alkalinity is deficient for coagulation. It is dissolved in the main filter building and conveyed some 400 ft. through a 1¼-in. iron pipe to the 42-in. line in the chamber. This treatment has seldom been employed and will not be necessary as long as sodium aluminate is used. A dose of 0.20 grain per gal. of aluminate supplies about 4 p.p.m. of alkalinity.

The water then enters the distribution chamber of the coagulation basin where it receives alum treatment, 1.0 grain per gal., or 143 lbs. per million gal. of aluminum sulphate. This reacts with the alkalinity of the water and with the sodium aluminate to produce the desired "floc" of aluminium hydroxide. The alum is dissolved in tanks in the main building and conveyed by gravity through 300 ft. of 2½-in. lead pipe to the point of application. Coagulation and sedimentation of impurities take place in the coagulation basin which is divided into two basins that operate in parallel. The capacity is 1.5 million gal., giving a nominal retention of 2.5 hours.

Filtration and Aëration. Settled water is distributed to the 10 filter beds in the main building from a concrete flume. Each filter bed is 20 x 24 ft. in dimension and contains 25 to 27 in. of sand. The combined area is 1/11 of an acre. Filtration is at the rate of 125 to 130 million gal. per acre per day. Filtered water is collected in a flume beneath the pipe gallery, from which it flows to an aërator. The latter consists of three troughs delivering water over a sloping surface that is studded with 4-in. riffle plates. The purpose of the aërator is to assist in removal of carbon dioxide and odors from the filtered water.

Corrective Treatment. As the filtered water leaves the aërator to pass to the clear water basin it drops over a steep sloping surface and then through a sluice gate. Excellent mixing takes place as a result. At the top of the slope a solution of soda ash is added to correct for corrosive

qualities that have been intensified by alum treatment. The amount has varied between 6 and 18 p.p.m. when alum alone was used as a coagulant, and between 4 and 8 p.p.m. with present practice that uses both alum and sodium aluminate.

Chlorination. A few feet beyond the point of soda application chlorine is fed into the final effluent of the plant. The dosage of chlorine is controlled by a Wallace and Tiernan vacuum-type solution-feed machine placed directly above the point of treatment. Disinfection is here employed as a finishing process to take care of any inequalities resulting from other steps in the process that may not be working at highest efficiency.

Distribution of the Final Effluent. The 3.5 million gal. clear water basin provides a retention of several hours before the chlorinated effluent passes to the city pumping station. The period of retention varies with the stage of pumping operations. Ordinarily a 20 m.g.d. pump is used for about eight hours twice each day. This arrangement at times puts an unequal burden of filtration upon the purification works. Pumping delivers the water to an open service reservoir at Payson Park, Belmont, where about 22 million gal. are stored.

Control of Chemical Feed. Filter operators make the round of the plant each hour of the twenty-four and check the rate of chemical feed with the Venturi indications of flow. Sodium aluminate is checked by weighing the discharge of the dry-feed machine for one minute. Alum and soda are discharged through calibrated orifices with an indicated setting. An hourly record is made of the drop in alum and soda tanks; chlorine tanks are weighed. A daily inventory is taken of the sodium aluminate in the valve chamber.

Records. All records of chemical feed, together with Venturi readings, hourly readings of losses of head, filter rates and levels of the clear water basin, and filter washing records go to the chemist each day. These furnish data for the calculation of plant performance. All daily and monthly computations are permanently filed.

The Laboratory. One of the authors of this paper has given full time attendance since the plant was started to operation of the plant and the conduct of the laboratory. Ample space and full equipment exist for all phases of water examination. Such daily tests are made as will guide the conduct of treatment and furnish a record of changes in quality. Complete analyses are made periodically and research is conducted to effect economies and improvements in treatment.

A generous policy of coöperation has been maintained between the Water Board and local educational institutions. Through access to the plant and laboratory students have been able to study rapid sand filters and to carry on important research. On the other hand the plant has had the benefit of outside opinions and the use of special apparatus for study of its problems.

Coagulation.

Coagulation is an initial and a major step in the rapid sand method of purification. Unless it is successfully accomplished, there will arise many baffling problems of filter operation and of effluent quality. Coagulation at the Cambridge plant has always demanded careful study and close regulation. The reasons for this are to be found in the changes in quantity and age of the organic matter in Stony Brook water, and in the mixing of Stony Brook and Fresh Pond waters, but principally in the limited period for subsidence in the coagulation basin. When the rated capacity of the plant, 14 m.g.d., is approached, as it is during many weeks of the year, the retention is only 2.5 hours. With raw water carrying a high content of organic matter, often in fresh condition, and no turbidity, this period is not long enough. Bottle experiments frequently show that precipitation of alum "floc" will scarcely begin within 2 to 2.5 hours. The great improvement that could be effected with a larger basin is demonstrable at any time by shutting down one or two of the ten filters and so increasing the period of subsidence.

Disposition of Wash Water. One of the disturbing factors influencing coagulation in the first years of the plant was the return of all filter wash water to the basin without settling. It was pumped from a receiving basin to a 12-in. perforated distribution pipe laid on the bottom of the basin about 20 ft. from the inlet channel. The return coincided with each filter wash and was at the rate of 1 700 to 3 400 g.p.m., $\frac{1}{8}$ to $\frac{1}{4}$ the rate of raw water flow. This lasted for several minutes, resulting in a temporary increase in the rate of flow through the basin, in a disturbance of bottom deposits, and in an addition of a large amount of impurities to the fresh water entering the basin. The pulsating effect produced made sedimentation less complete, and brought an added load upon the filters. The bacterial content of the settled water was increased and odors and tastes were intensified. All the impurities and precipitated alum that were removed by the filters were thrust back upon the basin. The pyramiding action rapidly reduced the available depth by deposits of sludge and so decreased the period of detention in the basin. Cleaning was necessary every three weeks.

In January, 1924, the wash water receiving basin was connected with the only available outlet from the plant, an 8-in. sanitary sewer. Experimentation showed that the water from each filter wash could be discharged by gravity through this sewer to the city sewer in 30 to 40 minutes. Comparative trials over monthly periods proved that elimination of wash water from the purification process gave better results in the coagulating basin, improved the odor, taste and color of the effluent and extended the filter runs from 16.8 to 18 hours. It also reduced pumping charges. Discharge of wash water to the sewer was, accordingly, made the regular practice. At times of heavy consumption, however, the sanitary sewer is not large enough to take all the water; the pumps are then used to return the surplus to the coagulation basin.

The only advantage of returning wash water is a conservation of 0.5 to 0.75 m.g.d. of water. If this becomes a future necessity it can be accomplished by the construction of wash water settling tanks, the effluent from which would be suitable to discharge into Fresh Pond. Preliminary studies have been made with this end in view.

Chlorination of Raw Water. Chlorination of raw water at the inlet valve chamber was carried on for several months in 1923-24. The purpose was to reduce the bacterial content of the basin water that was subject to high counts because of the return of wash water. A dosage of 0.3 p.p.m. was found efficacious. The practice was abandoned with the discharge of wash water to the sewer.

It was hoped at the time that the application of chlorine would improve coagulation and possibly decrease the amount of coagulant required. Weston[2] has reported such improvement when colored waters have been so treated. Repeated observations failed to indicate this advantage for chlorine. The reason for this is not clear; it may possibly lie in the chemical composition of the organic matter being different to that of the waters that showed a positive advantage for chlorination.

Control of Coagulation by Hydrogen Ion Determination. It may be said at the outset that attempts to govern the amount of coagulants by the resulting hydrogen ion concentration of the treated water have not shown that the best performance of the Cambridge plant can be secured by this means. Hydrogen ion determinations are made daily for all stages of treatment, and the results furnish information of value, as do other determinations, but sole reliance cannot be placed upon these results for guidance in chemical treatment. Inequalities in raw water due to pumping from Fresh Pond, changes in temperature, and fluctuations in quality and quantity of organic matter are all factors that dictate the amount of coagulant that is necessary.

The pH value of Stony Brook water ranges from 6.4 in the colder months to 7.2 in summer. The pH value of Fresh Pond water varies from 7.1 in winter to 7.8 in summer when algæ are consuming carbon dioxide, free and half-bound. Optimum coagulation using alum alone results with Stony Brook water in the production of a pH value in the treated water of 5.5 to 5.95 in winter and pH 5.8 to 6.3 in summer. There is unquestionably a certain range of hydrogen ion concentration within which coagulation is at optimum, but it is too broad to serve as the parameter of most efficient and economical treatment.

If the range of hydrogen ion concentration for successful results were narrow, the economical use of sodium aluminate would be impossible. Nine months operation with aluminate has shown its use to be both satisfactory and economical, at least under certain conditions of raw water.

The Use of Alum. Alum alone was used for coagulation up to December, 1926. The annual average amount employed, computed from monthly averages, was 189, 183, and 219 lbs. per million gal. for the first three years

of operation. Monthly averages varied in that time between a minimum of 165 lbs. per million gal. and a maximum of 247 lbs., that is between 1.15 and 1.73 grains per gal. The monthly averages of raw water color in the same time varied between 22 and 49 p.p.m.; the effluent color between 0 and 12 p.p.m.

Color removal has never been made the chief aim of operations, but as a matter of observation it has been found that the lowest effluent colors come incidentally with proper coagulation.

The most difficult water to coagulate is that from Stony Brook at times of heavy run-off. Whether this comes in warm months, or, as is more usual, in cold months, the organic matter is fresh from swamp sources and inter-

TABLE III.

BOTTLE EXPERIMENTS SHOWING TIME REACTIONS AND pH VALUES FOR COAGULATION OF RAW WATER.

Alum. Grains per Gal.	pH Value.	Formation of Floc. Time in Minutes.	Formation of Ppt. Time in Minutes.	Remarks.	Raw Water Conditions.
1.2	5.90	none overnight.			From Stony Brook
1.4	5.80	150	300		Color = 60
1.6	5.70	75	150	Optimum Dose	Alk. = 10
1.8	5.55	60	135		pH = 6.70
1.0	6.65	...	...		From Stony Brook
1.2	6.55	50	...		Color = 33
1.4	6.45	39	68	Optimum Dose	Alk. = 15
1.6	6.35	28	60		pH = 7.20
1.8	6.25	18	47		
1.0	7.05	120+	120+		From Fresh Pond
1.2	6.95	17	65		Color = 15
1.4	6.85	11	20	Optimum Dose =	Alk. = 21
1.6	6.75	6	14	1.2 to 1.4 grains	pH = 7.70
1.8	6.65	3	10		

feres with precipitation of alum. Cataphoresis experiments have shown the colloidal coloring matter at such times to be weakly negative in electrical migration properties, if not at times positive, thus interfering with neutralization of the charge carried by the colloidal alum "floc." It may also be that the colloidal coloring matter exercises a stabilizing influence and so prevents formation of "floc." Water high in color always gives a finely divided "floc" on the filters that penetrates the sand to a greater depth and favors longer runs.

Stored water, whether from Hobbs Brook reservoir or Fresh Pond, coagulates quicker and settles better than water fresh from the streams. It also requires smaller amounts of coagulant and produces a coarse "floc" that filters out near the surface of the sand. The colloidal matter is distinctly negative in its charge and the particles are probably larger in size as a result of agglomeration.

In Table III are given typical results of bottle experiments upon coagulation of different kinds of raw water.

The most serious problem in connection with the application of alum has been stoppage of the 300 ft. of 2½-in. lead pipe conveying the solution. The available head on this line is only 4 ft. and there are numerous bends. The solution is roughly filtered and is 2½ per cent. in strength, but fine insoluble material gradually decreases the flow through the pipe and necessitates use of a stronger solution. Abundant growths of Leptothrix, a filamentous organism, develop in the tanks and in the pipe from time to time and greatly aggravate the trouble. Daily flushing under pressure, weekly use of a strong bleach solution and periodical steaming are remedies in constant use, but they fail eventually to maintain a desired flow. It is then necessary to employ hand cleaning methods after taking down sections of the pipe.

The Use of Sodium Aluminate. After experimental runs with sodium aluminate its use was adopted for prolonged trial in December, 1926, and still continues. During the first few months an average dosage of 72 lbs. per million gal. was employed, that is 0.5 grain per gal. Later it was found advisable to reduce the amount and the dosage became 25 lbs. per million gal. or 0.17 grain per gal. The amount of alum necessary to give proper coagulation with aluminate has varied between 114 lbs. and 180 lbs. per million gal., equivalent to 0.8 to 1.25 grains per gal.

The primary reason for making use of aluminate was a desire to economize in chemical costs. After the experimental plant runs it was evident that the proportions of alum and aluminate necessary would result in a total cost for coagulant slightly greater than that with alum alone. There was a substantial saving, however, in the amount of soda ash used for corrective treatment. This resulted from the aluminate increasing the alkalinity of the raw water some 4 p.p.m. and from a diminished neutralization of alkalinity by the lower dosage of alum. A distinct benefit was derived from the new treatment within the plant itself. All the piping, valves and fittings now are exposed to water of lower corrosive properties.

Computations of chemical costs for the entire period of plant operation are given in Table IV.

A substantial saving is indicated from the use of sodium aluminate.

The dry product used gives upon analysis the following results:

Total $Al_2O_3 = 50$ per cent.
Total $Na_2O = 36$ per cent.
Ratio of Al_2O_3 to $Na_2O = 1.39$
Inert ingredients, as SiO_2 and $Fe_2O_3 = 14$ per cent.

Trouble was anticipated from deposition of the large amount of insoluble constituents that are incidental to manufacture. These have gone through to the basin, however, where they are handled with the sludge. The feeding of solid aluminate gives rise to serious difficulties at times.

TABLE IV.

Table Showing Cost of Chemical Treatment.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.
	Million gal. water		Tons of chemicals used.				Cost per ton.				Total cost.					Cost per million gal.				
Year.	Coagulated.	Corrected and chlorinated.	Alum.	Soda.	Chlorine.	Aluminate.	Alum.	Soda.	Chlorine.	Aluminate.	Alum.	Soda.	Chlorine.	Aluminate.	Comb. total cost.	Alum.	Soda.	Chlorine.	Aluminate.	Combined cost per million gal.
1923–4	4 032	3 975[1]	383.09	93.3	5.960	....	$31.00	$42.00	$145	....	$11 876	$3 919	$864	....	$16 659	$2.95	$2.20[1]	$0.22	...	$5.57[1]
1924–5	4 707	4 493	428.78	192.49	6.667	....	31.00	37.00	140	....	13 292	7 119	934	....	21 345	2.83	1.58	0.21	...	4.62
1925–6	4 614	4 429	504.85	255.23	3.994	....	31.00	32.60	140	....	15 650	8 320	560	....	24 530	3.39	1.88	0.13	...	5.40
1926–7[2]	4 865	4 670	523.09	303.16	3.828	....	31.00	32.40	150	....	16 216	9 822	574	....	26 612	3.34	2.10	0.12	...	5.56
1926–7[3]	4 865	4 670	446.78	196.39	3.850	58.50	31.00	32.40	150	$64.50	13 850	6 363	577	$3 773	24 563	2.85	1.36	0.12	0.77[5]	5.10
1927–8[4]	1 570	1 512	118.94	36.17	1.312	37.21	31.00	30.00	160	70.00	3 687	1 085	210	2 604	7 586	2.35	0.72	0.14	1.66	4.87

[1] These costs based on use of soda for corrective treatment during last six months of year, when 1 781 million gal. was corrected.
[2] Computations based on assumed use of alum as a coagulant for 12 months instead of use actually for 8 months.
[3] Computations based on actual use of alum only for 8 months and alum plus sodium aluminate for 4 months.
[4] Computations are for 4 months actual operation using both alum and sodium aluminate.
[5] This figure is low due to the cost of aluminate for 4 months being applied to the water coagulated during 12 months.

Its hygroscopic properties under humid conditions of the atmosphere cause caking and adherence to metal parts of the machine. The product is made nearby, packed in bags lined with sized paper and delivered in truck load lots. The problem of moisture would be a serious one with rail transportation and long storage, unless metal drums were used as containers.

Experiments in Baffling. The coagulation basin was built with one underflow baffle placed about 15 ft. from the inlet end, and extending from the top to within four ft. of the bottom. Inasmuch as there is no mixing basin, an attempt was made to promote mixing by replacing the old baffle in one side of the basin with one extending to the bottom and perforated with horizontal slots four in. in width and eight in. apart. This increased the velocity of flow and induced mixing. There was a slightly better deposition of sludge in this half of the basin. Other baffles were tried; the one now in place has 500 rectangular openings 2½ in. x 3 in. and increases the velocity momentarily from one ft. per min. to 30 ft. per min. During seasons of good coagulation the deposit of sludge in this side of the basin is considerably heavier and more compact than in the side containing the original baffle. There is no indicated difference when coagulation is poor.

Basin Cleaning. Normal conditions of operation require cleaning of the coagulation basin about once in four weeks. In the early spring the period of service is eight to twelve weeks; coagulation and sedimentation are then slow and the burden of removal is put upon the filters. There is a deposit of approximately 6 ft. of sludge, equivalent to 70 000 cu. ft., or 525 000 gal. It has a vegetable and earthy odor in winter; in summer decomposition often gives it a foul odor. Analyses made in winter show total suspended solids to be 3 200 p.p.m., volatile suspended solids 1 800 p.p.m., and fixed suspended solids 1 400 p.p.m. Thus the sludge contains a high percentage of organic matter; it has a low gravity and flows freely.

After drawing off the top water to Fresh Pond the sludge is pumped to the city sewer, and the basin is flushed with a fire hose. One side is cleaned one day, the other the next, thus enabling filtration to be maintained during the process. Examinations of the city sewers, which are laid on a flat slope in the vicinity of the plant, show no deposits or silting.

Filter Operation.

The filters were constructed and have been operated largely according to general practice for rapid sand plants. Each bed is a separate unit for all purposes, and is equipped with hydraulic valves, Venturi flow meter, Venturi control, and indicating and recording gages for loss of head and rate of flow. One special feature is the Wheeler filter bottom. There are 9½ in. of gravel of seven sizes and 27 in. of sand. No failures of structures have been noted and no displacement of the Wheeler bottom or gravel.

Filter Sand. Specifications called for 27 in. of sand. Beds No. 8, 9, and 10 were filled with bank sand from Wilbraham, Mass. A railroad embargo, due to the coal situation, made it necessary to obtain sand for the

other beds from local stocks. Ipswich River sand was selected although it contained some 12 per cent. of fine material that had to be scraped from the beds after washing. A few months after starting the plant, about two in. of fine material was scraped off and an equal amount of coarse Plum Island sand added in an endeavor to increase the periods of filter service. Stock sand from these three sources had the following sizes:

Sample.	Effective Size.	Uniformity Coefficient.
Wilbraham	0.38–0.41 mm.	1.76–1.91
Ipswich River.....	0.31	1.52
Plum Island.....	0.66	1.48

Analyses of material from the various beds have been made from time to time. Some of these appear in Table V.

TABLE V.

SIZES OF SAND AT DIFFERENT TIMES.

Filter No.	Effective size in mm.				Uniformity coefficient.			
	Feb. 1923.	Nov. 1923.	Mch. 1926.	Aug. 1927.	Feb. 1923.	Nov. 1923.	Mch. 1926.	Aug. 1927.
Samples from Total Depth of Beds.								
1	.36	.42	.44	.46	1.53	1.43	1.55	1.61
2	.36	.42	.48	.49	1.47	1.45	1.70	1.53
3	.37	.43	.46	.47	1.37	1.40	1.58	1.60
4	.37	.45	..	.47	1.41	1.46	...	1.62
5	.38	.45	.46	.46	1.45	1.38	1.59	1.61
6	.38	.44	.45	.46	1.45	1.35	1.64	1.72
7	.39	.44	.49	.45	1.51	1.36	1.50	1.60
8	.39	.49	.52	.48	1.77	1.53	1.59	1.67
9	.40	.48	..	.47	1.70	1.45	...	1.70
10	.40	.48	.54	.51	1.70	1.45	1.57	1.59
Aver.	.38	.45	.48	.47	1.53	1.43	1.59	1.62
Samples from Top Inch of Beds.								
1	..	.38	..	.36	...	1.31	...	1.37
2	..	.41	..	.37	...	1.40	...	1.33
3	..	.40	.37	..	...	1.25	1.41	...
4	..	..	..	..	...	...	...	...
5	..	..	..	.35	...	...	...	1.43
6	..	.40	.37	..	...	1.30	1.45	...
7	..	.40	..	.39	...	1.32	...	1.31
8	..	..	..	.35	...	...	...	1.46
9	..	..	.36	..	...	...	1.39	...
10	.32	.40	..	.36	1.34	1.35	...	1.42
Aver.	..	.40	.37	.36	...	1.32	1.42	1.38

Note. An average depth of 3.5 in. of new Ipswich sand was added in July, 1926.

It will be noticed that the effective size has increased from an average of 0.38 mm. to 0.47 mm. This is largely due to growth of the grains by adherence of alum "floc" and organic matter. Very little sand has been lost

from the beds. Readings made after three years of operation recorded a maximum loss of two in. and an average of one in. per bed. Beds were scraped free of surface mud deposits after that time and three to five in. of new Ipswich River sand were added. Present sizes appear in the table.

Rates of Filtration. Rates of filtration have varied with consumption, the range being from 118 to 136 million gal. per acre per day. The average daily volume of water filtered has exceeded 14 million gal. in three different months and has been more than 13 million gal. in 29 months out of a total of 51 months of operation. Considerable difficulty has been experienced at times in keeping pace with consumption. A longer period of subsidence in the coagulating basin would give relief by lightening the load of purification that is placed on the filters.

Periods of Filter Service. Periods of filter service average from 8 to 22 hours, being shortest in summer and longest in the winter and early spring. Summer brings raw water that coagulates with a coarse "floc"; the "floc" forms a sticky, compact coating on the sand surface and offers resistance to filtration. Water fresh from stream sources produces a fine "floc" that penetrates the sand, offers less resistance to filtration, and tends to break through the filters as head losses increase. Algæ in Fresh Pond water also contribute to shorter runs in the summer, especially if they are of the blue-green varieties. Diatoms have less effect.

The stored water of Fresh Pond coagulates easier and quicker at any time of year than does Stony Brook water. For the past two years about four m.g.d. have been pumped from Fresh Pond in cold weather when coagulation is poorest. A coarser "floc" is obtained that filters better and prevents breaking. Without this procedure it is necessary to stop filter runs at 6 or 7 ft. loss of head instead of the usual 8.5 to 9 ft. There is no question that finer sand would better serve winter conditions, but in summer it would be impossible to meet the maximum demand for water. The first summer of operation demonstrated this fact.

An interesting study of losses of head in the Cambridge plant was made in 1926 and reported to this Association by Professor Tyler[3] of the Massachusetts Institute of Technology.

Filter Washing. Filter washing calls for the use of some measures that are not commonly employed by plants. At the end of a period of service the water on the filter is drawn down below the surface of the sand. This practice traps a certain amount of air that is advantageous in breaking up the surface of the bed when wash water enters. The ordinary method of drawing water down to the level of the troughs before washing allows masses of sand to come dangerously near the crest of the trough when washing begins; furthermore, when this is done washing is not as complete in a given time. Special measures, employed periodically, are discussed under Special Treatment of Beds.

Filtered water, pumped from the flume to a steel tank, is supplied by gravity for washing. The velocity of wash water builds up gradually and

is held constant by Venturi control, thus doing away with hand control and avoiding excessive velocities. The Wheeler bottom provides a very uniform distribution of water.

Experience has dictated the necessity of thorough washing to prevent building up of mud banks and mud balls. The final wash water is, therefore, clean in appearance. An expansion of sand approaching 30 per cent. is necessary and a washing period of two and one-half minutes at maximum velocity. To obtain an expansion of 30 per cent. with the size of sand used requires a vertical velocity of 27 in. at a temperature of 70°F. In the winter, with temperatures near 38° the viscosity and supporting power of the water are much greater; 30 per cent. expansion is then obtained with a velocity of about 20 in. The use of this lower velocity has resulted in an

TABLE VI.

EXPERIMENTS ON EXPANSION OF SAND DURING WASHING.

Filter No.	Temp. F°.	Effect. Size mm.	Uniformity Coeff.	Velocity of Water in. per min.	Depth Sand in.	Expansion of sand.	
						in.	Per cent.
5	40	0.46	1.61	18.5	25.0	6.0	24
5	40	0.46	1.61	18.5	25.0	6.0	24
3	40	0.47	1.60	18.5	27.0	7.5	28
3	40	0.47	1.60	22.0	27.0	7.5	28
6	40	0.46	1.72	22.0	26.5	8.5	32
8	40	0.48	1.67	22.0	28.0	8.0	29
10	40	0.51	1.59	22.0	27.5	9.0	33
5	40	0.46	1.61	22.0	25.0	8.0	32
5	40	0.46	1.61	22.0	25.0	8.0	32
8	40	0.48	1.67	28.0	27.5	11.0	40
4	50	0.47	1.62	24.0	24.5	7.0	29
5	50	0.46	1.61	24.0	25.0	6.5	26
3	50	0.47	1.60	24.0	27.0	8.0	30
7	62	0.45	1.60	24.0	27.0	7.5	28
7	63	0.45	1.60	24.0	27.0	7.5	28
7	63	0.45	1.60	27.0	27.0	8.5	22
1	66	0.46	1.61	22.0	26.0	6.0	23
7	66	0.45	1.60	22.0	27.5	6.0	22
1	66	0.46	1.61	28.0	26.0	8.5	33
7	66	0.45	1.60	28.0	27.5	8.5	31
1	72	0.46	1.61	27.0	26.0	7.5	29

economy of 150 000 to 200 000 gal. of wash water per day during the coldest months. Intermediate velocities are employed for spring and fall. In Table VI will be found the results of experiments on sand expansion.

The monthly average of wash water during the past year has varied between 2.1 per cent. of the total filtered in the month of February and 6.3 per cent. in the month of November.

Sand Shrinkage and Cracking. The phenomenon of sand shrinkage with development of cracks along the sidewalls has been observed annually at the Cambridge plant. It is most pronounced in summer and practically absent in the winter. At its worst it is accompanied by fine cracks over the sand surface; these develop toward the end of filter runs. Shrinkage

from the walls allows a large amount of water to pass downward at the edges of the bed; deposits of alum precipitate and organic matter build up rapidly into banks, bind the sand grains together and make hard masses that are only partially disintegrated by the washing process. The trouble was very acute during the first summer of operation, shrinkage cracks developing 3 in. in width and 12 in. deep. Remedial measures have since been developed that give relief.

Strange to say, coagulation is at its best and the filtered water is free of turbidity and color when shrinkage is at its worst. In our opinion the coarse "floc" is taken out on the surface of the sand and forms a compact, sticky blanket that resists the flow of water and holds the sand grains together, so that the whole upper sand layer is compressed and pulled away from the walls. High temperatures may also play a rôle by modifying the physical properties of the alum precipitate, making it more gelatinous. With the arrival of high colored water and the formation of a fine "floc" conditions rapidly improve. Shrinkage has been slight during the present summer when high colored water has resulted in coagulation with finer "floc."

The 20° bacteria in the filtered water have usually been high in summer, often reaching several hundred per c.c. and exceeding the number in the coagulated water. The source of these bacteria is in the sand of the filters. They are too numerous to represent water poorly filtered as a result of shrinkage. It is possible, however, that shrinkage and cracking have resulted in the lower layers of sand becoming dirtier than usual, and that opportunity has thereby been provided for development of bacteria in the beds. Chlorination has effectually disposed of these bacteria in the effluent, 0.25 p.p.m. of chlorine being enough to give a nearly sterile effluent.

Bacteria counts on filtered water have been low during the present summer. The condition parallels the reduced prevalence of shrinkage cracks and the high organic content and poorer coagulating properties of the raw water.

Special Treatment of Beds.

The routine washing of beds with high velocities and prolonged application of wash water does not suffice alone to keep the sand clean and to prevent caking and the formation of mud balls in the sand. Two special methods of treatment have been found necessary to maintain satisfactory conditions, hand raking around the sides, and treatment with caustic soda.

Hand raking is carried out every ten days, one bed being so treated each day. This practice requires two men, each of whom handles a rake with 10-in. tines set at right angles to a long wooden handle. From the walls of the filter the rake is worked up and down in the sand during a wash. The mechanical agitation effectually breaks up the mud banks that form along shrinkage cracks. These banks do not form in the center of the

beds. Conditions at Cambridge are not unusual for rapid sand filters. Reports have come from other plants of various methods devised to increase the agitation that is provided by simple washing with water. These attempts recall former practice that made use of the air wash and mechanical stirrers.

Caustic treatment is intended to take care of mud balls and deposits on the sand grains. The procedure is to wash a bed and leave about 12 in. of water upon it. Dry caustic soda is then added in an amount to give a 0.25 per cent. solution. The solution is drawn down into the sand and the bed allowed to stand overnight. On the following morning the solution, at that time dark brown in color, is filtered to waste and the bed is washed. Sometimes the surface is thinly scraped. It is necessary to use caustic treatment once or twice each year. It disintegrates mud balls, dissolves aluminium deposits and loosens adhering organic material from the sand. The latter is always visibly cleaner after treatment.

Beds No. 1 and 2, particularly No. 2, have given more trouble from accumulation of dirt than the others. This is due to masses of alum

TABLE VII.
RESULTS OF AËRATION OF FILTERED WATER.

	CARBON DIOXIDE.	DISSOLVED OXYGEN.	
	p.p.m.	p.p.m.	Per cent. Saturation.
Before Aëration	10.5	8.7	83
After Aëration	7.5	9.8	95

"floc" and organic matter that roll along the settled water flume, much as dust balls roll along a smooth floor. The material is disgorged at the end of the flume upon these two beds. The masses are often large enough to resist expulsion from the sand during washing. They tend to bind the sand grains together and so cause caking. The trouble could be largely eliminated by a blow-off at the end of the flume. It is now very difficult to clean.

AËRATION.

The riffle plate aërator is not a particularly efficient type but it does effect a partial removal of carbon dioxide and of odors. At the same time the oxygen saturation is increased. Typical results of aëration appear in Table VII.

CORRECTIVE TREATMENT OF CORROSIVE PROPERTIES.

The coagulation of soft waters with aluminium sulphate is bound to increase their ability to attack metals, unless the tendency is combated by supplementary treatment. There are too many such cases on record to require an elaboration of this statement.

It is a sign of the times, and of the rising standards of quality, that *preventable* corrosion must not be the sin of a public water supply. In the

present state of knowledge there exists no feasible method of eliminating *all* corrosion from water systems using soft water.

We in Cambridge have had to face the preconceived belief held by some that rapid sand filtration would by its very nature add greatly to any corrosion troubles experienced with the old raw water supply. The policy followed to date has been to furnish water as nearly like the untreated supply as possible in mineral constituents and no worse in its tendency to dissolve metals. How far beyond this point the future may carry us cannot be said. To effect further improvement will entail either, (1) adding appreciably to the cost of treatment or, (2) increasing the hardness of the water.

Six months operation of the new plant showed conclusively that without corrective treatment of some kind Cambridge would realize the predictions of the skeptics and become a "red water" town. Also, it was evident that the lower carbonate and higher sulphate content of the water was displacing the former soft carbonate scale in steam boilers with a hard, compact, crystalline sulphate scale.

The remedy that seemed most advantageous was to use soda ash. Solution tanks and feeding devices already were in place for adding this to the raw water in emergencies. Additions were made to the piping so that soda ash could be added to the aërated effluent. Treatment has been continuous since November, 1923. A dosage of 50 to 150 lbs. per million gal., giving an added alkalinity of 6 to 18 p.p.m., has been employed when alum alone was used, and from 35 to 65 lbs. per million gal., giving 4 to 8 p.p.m. of alkalinity with present treatment using both alum and sodium aluminate. Thereby, the hardness has not been increased and non-carbonate, or incrusting hardness, has been reduced by the same amount that the alkalinity has been raised. Hydrogen ion values of the final effluent last year averaged pH 6.95.

Lime versus Soda. The question is naturally often asked, "Why is lime not used? It is cheaper." There are three reasons. First, mixing and feeding devices for soda ash were available; from the standpoint of operation it was expedient to use them. Second, the use of lime would not reduce the incrusting solids of the filtered water; there was evidence that boiler trouble had increased after purification began. Third, Cambridge water, measured by the quality of many nearby communities, is moderately hard. Application of lime for corrective treatment would add approximately 40 per cent. to the existing hardness, which is 28 p.p.m.

Behavior of Old Pipes. When clean water is turned into old pipes that are lined with deposits and tubercles it frequently happens that there is disintegration of these and a resulting epidemic of red water for a considerable time. No such experience was encountered, but observations point to a gradual loosening of old deposits that have tended to migrate to distant parts of the city and into dead ends. Many of the larger mains were cleaned prior to the beginning of filtration.

Algæ Trouble.

Reference has been made to the fact that the storage reservoirs on the Stony Brook catchment area have not been productive of large growths of microscopic organisms, particularly of those genera causing bad odors and tastes. Extracted vegetation has been responsible for decided vegetable and musty odors and tastes on one or two occasions following the melting of snow and a heavy run-off.

The Fresh Pond reservoir has always been famous for the wealth of its microscopic life. Production has not increased since it became a reserve source of supply; it has decreased somewhat, but heavy growths have developed occasionally in the last four years. Blue-green algæ and diatoms have then flourished to the extent of several thousand standard units per cubic centimeter.

The diatoms impart vegetable and aromatic odors, sometimes distinct, more often faint. They do not appreciably reduce the length of filter serv-

TABLE VIII.

Days after Treatment.	Microscopic Organisms Stand. Units per c.c.	Remarks.
0	1 200	300 stand. units of Anabæna, balance Synedra.
1	320	Cells badly faded. Mostly Synedra.
2	660	Synedra 500 units, Anabæna 150 units. Cells faded and disrupted.
3	460	Cells faded and broken.
4	430	Nearly all Synedra.
6	875	Nearly all Synedra.
10	960	Nearly all Synedra.
23	360	All Synedra.

ice; many of them are precipitated in the coagulation basin. The blue-green varieties are the worst offenders, giving the water a musty or grassy odor, refusing to settle appreciably, and by virtue of their gelatinous properties clogging the sand and reducing filter runs. Their occurrence coincides with the heavy consumption periods of late summer and fall. It has been necessary to resort to treatment of Fresh Pond with copper sulphate. This has been done from one to three times each season, microscopical analyses being used to indicate the necessity.

Treatment of Fresh Pond. The area of the pond is 160 acres, of which 37 acres are in a bay on the east side. The intake is in the bay at a depth of 10 ft. Treatment usually is confined to this bay, but it is occasionally extended to another smaller bay around a point of land and into which the inlet discharges. A dose of 400 lbs. of copper sulphate is applied to the larger bay by suspending bags over the gunwales of a rowboat. An outboard motor supplies power and lanes are covered about 25 ft. apart. Two men are required for one day to carry out this programme.

The dosage of copper sulphate is 0.25 p.p.m., or 2 lbs. per million gal., based upon the entire depth of water. During the period of summer stagnation there is little microscopic life below a depth of 10 or 15 ft. The effect of the copper sulphate is carried beyond this depth very slowly. If the dosage is calculated on a basis of 10 ft. of depth it becomes 0.58 p.p.m., or 4.8 lbs. per million gal. It is within this zone that most of the organisms are found. No fish have been killed by the treatment.

A reduction in the bulk of the growth is spread over several days, during which the microscope reveals many cells that have lost much of their coloring matter and life substance. The destruction of blue-green algæ is often followed by the multiplication of diatoms and nearly always by an increase in bacteria. Table VIII gives a typical record of events following the application of copper sulphate, as above described, on August 8, 1926.

Following the application of the algicide and the disappearance of blue-green organisms there is a longer period of service for the filters. The increase is not great but is noticeable, being from 2 to 3 hours. It brings relief to the plant when it is most needed.

Results of Purification.

The foregoing pages have confined discussion to methods of operation and to the problems attendant upon operation. This leaves two subjects for consideration that measure the success of the purification processes employed, first, the character of the water turned out; second, the cost of its production.

In Table IX will be found a summary of daily laboratory tests representing certain physical, chemical and bacteriological properties of the water in various stages of purification. These are arranged by years for the four years of operation, May, 1923, to March, 1927, inclusive. Average, maximum and minimum figures are given that have been compiled from monthly averages. Extreme maximum and minimum values for any one day, therefore, do not appear. Supplementing this is Table X that gives similar values for operating data of the plant.

For purposes of discussion only the last year's results will be considered. They represent the year of maximum consumption and the year yielding the most difficult water to treat.

Physical and Chemical Qualities. The average turbidity of the raw water was 2 p.p.m. and the average color 42 p.p.m., the maximum monthly averages being 4 and 52, respectively. Coagulation and sedimentation resulted in the settled water having an average turbidity of 3 p.p.m., slightly higher than the raw water, and an average color of 31 p.p.m. These figures fairly represent the performance of the coagulation basin which allows a detention of only 2.5 hours.

The final effluent had an average turbidity of 0 and an average color of 4. The maximum effluent color was 10, the minimum 0.

TABLE IX.

SUMMARY OF PHYSICAL, CHEMICAL AND BACTERIOLOGICAL ANALYSES.
Compiled from Monthly Averages of Daily Results.
(Results given are p.p.m. unless otherwise stated.)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.
Values.		Turbidity.			Color.			Alkalinity.			Carbon Dioxide.			pH Value.			Bacteria per c.c. Gelatine at 20°C.				Bacteria per c.c. Agar at 37°C.				Bacterium Coli per 100 c.c.			
	Temp. F°. eff.	Raw.	Cong.	Eff.	Raw.	Cong.	Eff.	Raw.	Cong.	Eff.	Raw.	Cong.	Eff.	Raw.	Cong.	Eff.	Raw.	Cong.	Filt.	Eff.	Raw.	Cong.	Filt.	Eff.	Raw.	Cong.	Filt.	Eff.
May 1923 to March 1924.																												
Average	54.0	3	..	−1	34	..	4	15.5	...	9.0[1]	3.0	...	6.0	...	...	...	400	...	200	7	90	..	5	3	16	..	0.3	0
Maximum	69.5	5	..	2	49	..	12	20.0	...	18.0	6.5	...	7.0	...	...	...	700	...	700	27	275	..	17	10	39	..	1.0	0
Minimum	40.0	2	..	0	20	..	0	11.0	...	5.0	0.5	...	4.5	...	...	...	120	...	12	1	39	..	1	0	3	..	0	0
April 1924 to March 1925.																												
Average	53.0	3	5	−1	37	27	2	17.0	7.0	15.5	3.0	13.5	4.0	...	...	...	850	750	550	22	130	45	6	1	21	0.3	0.2	0
Maximum	72.0	4	10	1	44	44	5	21.5	11.0	19.0	6.0	17.5	6.5	...	...	...	3,700	3,100	3,000	90	550	200	35	4	62	1.0	2.0	0
Minimum	37.0	2	2	0	25	9	0	11.5	3.0	12.0	1.0	11.0	2.0	...	...	...	275	240	8	2	36	5	0	0	0	0	0	0
April 1925 to March 1926.																												
Average	53.0	2	4	−1	38	29	3	16.0	5.5	17.0	3.0	14.5	3.5	6.90	5.85	6.85	425	375	250	5	100	37	4	1	8	0	0	0
Maximum	72.0	3	7	−1	48	45	6	19.5	7.0	19.5	5.5	17.0	4.5	7.15	6.05	7.00	800	650	650	17	170	100	16	3	16	1	0	0
Minimum	38.0	2	2	0	27	11	0	12.5	4.0	13.5	2.0	12.5	2.5	6.65	5.70	6.75	210	120	27	1	48	9	1	0	2	0	0	0
April 1926 to March 1927.																												
Average	54.0	2	3	0	42	31	4	14.0	8.0[2]	16.5	4.0	11.5	3.5	6.80	6.20	6.95	240	160	150	2	90	37	6	1	10	0.6	0.1	0
Maximum	70.0	4	5	−1	52	42	10	17.5	12.5	18.5	6.5	14.0	4.5	7.10	6.60	7.10	450	275	425	4	160	55	27	3	26	1.9	0.4	0
Minimum	40.0	2	2	0	30	14	0	10.5	3.0	14.0	2.0	7.0	2.0	6.50	5.80	6.80	140	90	11	1	36	14	1	0	1	0	0	0

Notes. [1] Soda ash used for 5 months only in 1923–24.
[2] Sodium aluminate used for 4 months in 1926–27.

TABLE X.

Summary of Operation and Chemical Treatment.

Compiled from Monthly Averages of Daily Results.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
Values.	Volumes of water in millions of gallons.						Wash Water (per cent.)	Length of Runs (Hours.)	Million gal. per acre per day.		Average loss of head in feet.		Electricity in K.W.H.	Chemicals, lbs. per million gal.			
	From Stony Brook.	From Fresh Pond.	Total Filt.	Sent to City.	Wash Water.												
					Pumped	Used.			Yield.	Rate.	Initial.	Final.		Alum.	Sodium Alumin.	Soda.	Chlorine
May 1923 to March 1924.																	
Average	10.58	1.70	13.04	12.21	0.83	0.58	4.5	9.8	119	126	1.0	8.3	543	189	...	98[1]	2.9
Maximum	12.50	8.02	14.00	13.03	1.43	1.10	8.0	18.1	126	131	1.2	9.3	1 461	216	...	141	3.6
Minimum	4.30	0.26	12.32	11.69	0.48	0.26	2.0	3.7	111	118	0.8	5.7	202	165	...	54	2.0
April 1924 to March 1925.																	
Average	11.11	1.72	13.02	12.19	0.85	0.68	5.2	11.1	118	128	0.9	8.6	434	183	...	86	2.9
Maximum	12.84	4.68	14.03	13.30	1.25	1.00	7.8	14.9	126	133	1.0	8.9	810	203	...	112	6.8
Minimum	8.24	0	12.18	11.39	0.60	0.48	3.7	6.9	109	118	0.8	6.9	178	166	...	52	1.1
April 1925 to March 1926.																	
Average	10.60	2.05	12.75	12.15	0.60	0.46	3.5	14.1	116	125	0.8	8.5	382	219	...	115	1.8
Maximum	11.90	4.57	13.60	13.00	0.86	0.69	5.3	18.2	122	129	1.0	8.8	598	247	...	151	2.1
Minimum	8.87	0.06	11.89	11.28	0.45	0.32	2.7	10.2	110	122	0.6	7.4	146	172	...	183	1.5
April 1926 to March 1927.																	
Average	11.19	2.14	13.47	12.79	0.66	0.49	3.6	12.2	122	131	0.9	8.5	404	184	71[2]	86	1.6
Maximum	12.56	4.58	14.10	13.45	1.16	0.89	6.3	18.7	127	134	1.1	9.0	603	217	78	123	1.8
Minimum	8.54	0.13	12.72	12.21	0.43	0.27	2.1	6.6	115	127	0.8	6.9	159	150	65	40	1.5

Notes. [1] Soda ash used for five months only in 1923–24.
[2] Sodium aluminate used for four months only in 1926–27.

The average alkalinity of the raw water was 14 p.p.m., the maximum monthly being 17.5 and the minimum 10.5. These are the lowest values of any of the four years. Coagulation reduced the alkalinity to an average value of 8 p.p.m., and this was corrected after filtration by addition of soda ash, so that the final effluent carried an alkalinity of 16.5 p.p.m., an average of 2.5 p.p.m. more than the raw water.

Carbon dioxide averaged 4 p.p.m. in the raw water, 11.5 p.p.m., in the coagulated and 3.5 p.p.m. in the final effluent.

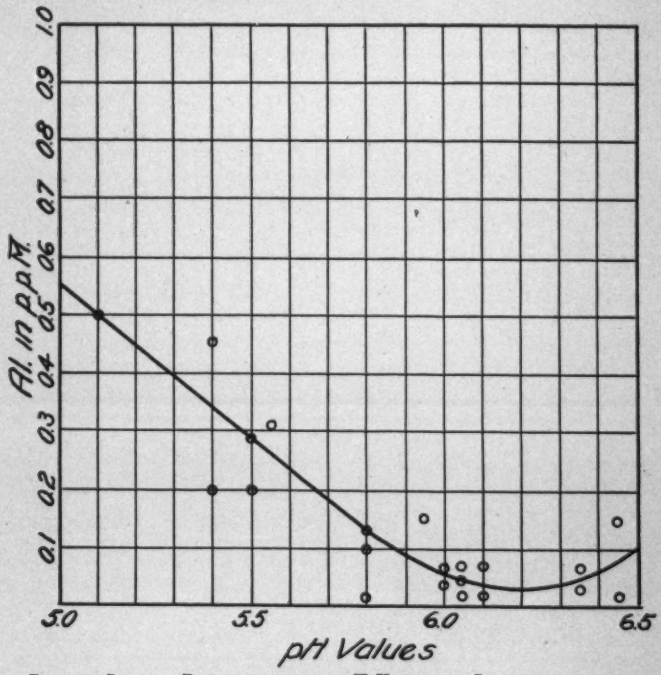

DIAGRAM SHOWING RELATION BETWEEN pH VALUE AND SOLUBLE ALUMINIUM IN CAMBRIDGE FILTERED WATER.

The pH value of the raw water averaged 6.8 with a monthly maximum of 7.1 and a minimum of 6.5. That of the coagulated water averaged 6.2 and of the final effluent after addition of soda ash 6.95.

Bacteriological Qualities. The bacterial content of the raw water for the last year of operation, 1926–27, was somewhat lower than that of other years. The average number of bacteria in the raw water developing at 20° was 240 per c.c., the monthly maximum being 450 and the minimum

140 per c.c. The highest monthly average ever recorded was that of February, 1925, which was 3 700 per c.c.

The coagulated water in 1926–27 contained an average of 160 20° bacteria, 65 per cent. of the number in the raw water, and the filtered water contained an average of 150 per c.c. The final effluent had an average of 2 per c.c.

The 37° bacteria for the raw, coagulated, filtered and effluent waters averaged for the year 90, 37, 6 and 1 per c.c., respectively, showing a more consistent and uniform removal for different stages of purification than did the 20° bacteria.

The Bact. coli index per 100 c.c. of sample averaged for the raw, coagulated, filtered and effluent samples 10, 0.6, 0.1 and 0.

Aluminium Content. There is another constituent of alum-treated waters that measures the efficiency of coagulation and filtration; that is the aluminium content. Numerous tests made upon the filtered water have shown values for aluminium ranging from .02 p.p.m., the slightest trace, to 0.5 p.p.m. The great majority of tests have shown less than 0.2 p.p.m. The largest amounts are found in the cold months when coagulation and sedimentation are poor and when the filters have a tendency to break at losses of head of about 6 ft. At such times, also, the coagulated water is most acid and shows lowest pH values. Exactly opposite conditions prevail in the summer when the smallest amounts of aluminium have been recorded.

The accompanying diagram shows the relation between the pH values and the amount of aluminium in the filtered water. The smallest amounts have been found when the pH value ranged from 6.0 to 6.3. It has been observed by Hopkins[4] that with increasing acidity there is poorer coagulation and a larger content of sulphate in the precipitate of alum "floc." Such "floc" undoubtedly manifests a greater tendency to pass filters and possibly to go back into solution as it is continuously washed with clean water in the pores of the filter.

Following the use of sodium aluminate the pH values of the coagulated water have been higher and the average of aluminium readings have been lower.

Summary of Results of Purification. Rapid sand filtration at Cambridge has dealt with a raw water stained with the extract of dead vegetation, dull in appearance, impregnated with odors and tastes from dead and living plants, at times distinctly corrosive toward metals and always liable to adventitious entrance of the germs of water-borne diseases. The result of purification has been the production of a drinking water that is nearly colorless, brilliant in appearance, and uusally free from noticeable tastes and odors, without hardness in excess of that of the raw supply, with corrosive tendencies reduced rather than intensified, and with a bacterial content that rivals the purest natural waters and precludes the possibility of water-borne diseases entering the community through the medium of the water supply.

Costs of Purification.

During the year ending March 31, 1927, there were filtered an average of 13.47 m.g.d., of which 12.79 m.g.d. were sent to the city. The expenditure of plant effort necessary to accomplish this is shown in Table X. The average yield of the plant was at the rate of 122 million gal. per acre per day and the average rate of filtration was 131 m.g.d.

The wash water pumped was 660 000 g.p.d., of which 170 000 gal. remained on the beds after washing, leaving 490 000 gal. wasted to the sewer. The wash water wasted was, therefore, 3.6 per cent. of the total filtered. The average period of filter service was 12.2 hours, the maximum monthly average being 18.7 hours and the minimum 6.6 hours. Losses of head ranged, as an average, from 0.9 ft. initial to 8.5 ft. final. Nine feet is a maximum beyond which normal rates of filtration cannot be maintained.

Cost figures for purification appear in Table XI. They cover the three years 1925, 1926 and 1927, ending March 31. Total costs and costs per million gallons *filtered* are given and these are divided into five items: (1) Chemicals, (2) Labor, (3) Laboratory, (4) Power and Fuel, (5) Equipment, Service and Supplies.

TABLE XI.

Operating Cost Data Cambridge Water Purification Works.

Item.	Total cost. Year ending March 31.			Cost per million gal. filtered. Year ending March 31.		
	1925.	1926.	1927.	1925.	1926.	1927.
Chemicals	$214 35.00	$24 530.00	$24 563.00	$4.53	$5.32	$5.05
Labor, operators, etc.	175 64.00	18 798.00	19 864.00	3.75	4.07	4.08
Laboratory, chemists, supplies, gas	3 555.24	3 904.83	3 798.63	0.76	.85	.78
Power, Lights and Fuel	6 621.98	5 396.02	5 838.27	1.41	1.17	1.20
Equipment, Service and Supplies	1 352.92	1 147.26	1 351.48	.29	.25	.28
Totals	$50 529.14	$53 776.11	$55 415.38	$10.74	$11.66	$11.39
Million Gal. Filtered.	4 707	4 614	4 865	....	....	....

The total costs for the past three years have been $50 529, $53 776 and $55 415. The water filtered has been 4 707, 4 614 and 4 865 million gal., thus giving costs per million gal. of $10.74, $11.66 and $11.39. These figures do not include any portion of the fixed charges for construction.

Costs for chemical treatment are given in greater detail in Table IV.

References.

[1] Rapid Sand Filtration at Cambridge, Mass., by George A. Johnson. Jour. N.E.W.W.A., Vol. xxxvii, p. 339, 1923.

[2] The Use of Chlorine to Assist Coagulation, by Robert Spurr Weston. Jour. A.W.W.A., Vol. xi, p. 446, 1924. The Decolorization of Soft Waters, by Robert Spurr Weston. Water Works, Vol. lxvi, p. 308, 1927.

[3] Head Losses in the Rapid Sand Filters at Cambridge, Mass., by Richard G. Tyler, W. A. Danielson and Maurice Lebosquet, Jr. Jour. N.E.W.W.A., Vol. xl, p. 332, 1926.

[4] Composition of Alum Floc in Mixing Basins, by Edward S. Hopkins. Jour. A.W.W.A., Vol. xii, p. 405, 1924.

DISCUSSION.

MR. L. H. ENSLOW.* I would like to ask a question as to the method of calculating the 2.5 per cent. caustic solution. Is the calculation based on 12 in. of water in the filter box above the sand, or on the entire depth of water in the filter box?

PROFESSOR WHIPPLE. It is based upon the entire body of water — 12 in., or whatever it may be, above the sand, plus that contained in the sand.

MR. ENSLOW. How much water do you figure is contained in the sand?

PROFESSOR WHIPPLE. Forty or fifty per cent. of the sand volume is void space and therefore filled with water.

MR. ENSLOW. In your researches have you tried varying the rates of wash water with different elevations of wash water above the sand bed to determine the most economical combination of rise and wash and the distance between the trough edge and the sand level?

PROFESSOR WHIPPLE. That has not been done. Although the troughs, of course, are fixed in position, it could be done experimentally. It has not been tried out.

MR. ENSLOW. What method do you use for determining the residual alum?

PROFESSOR WHIPPLE. A modification of the Hatfield method.

MR. E. SHERMAN CHASE.† I would like to inquire if there has been any trouble with algæ growths in the open reservoir.

PROFESSOR WHIPPLE. No, there has been no trouble whatever. The only algæ I have seen in Payson Park Reservoir are a few of the attached shore forms that come in the summer; not enough to do damage. Why growths do not occur, I do not know. They should.

MR. ENSLOW. Has the sodium aluminate decreased the per cent. of wash water?

PROFESSOR WHIPPLE. Not to an appreciable extent. I do not believe that coagulation is any better with sodium aluminate or that the results through the filters are any better. Sometimes they are not quite so good. We have not completed a full year's run with this chemical and will have a fuller judgment to pronounce on it later on.

A MEMBER. Is the aërating device which you have at Cambridge pretty efficient?

PROFESSOR WHIPPLE. I have a paragraph in the paper in regard to the aërator and what it does. It removes about three parts out of ten parts of carbon dioxide. Any riffle plate aërator is bound not to be very efficient in the removal of gases.

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*Sanitary Engineer, The Chlorine Institute, New York, N. Y.
†Of Metcalf and Eddy, Consulting Engineers, Boston, Mass.

SAND EMBANKMENT IMPOUNDING DAM AT CHICOPEE, MASS.

BY MYRON G. MANSFIELD.*

[*Read September 14, 1927.*]

HISTORICAL.

The city of Chicopee is located in Hampden County, in the valley of the Connecticut River, adjoining the city of Springfield on the north. It is a manufacturing city with diversified industries, having an area covering approximately twenty-four sq. miles and includes, beside Chicopee itself, Chicopee Falls, Willimansett, Fairview and a part of Brightwood.

The city has had a substantial growth in the past twenty years, the federal census giving it a population of approximately 11 300 in 1880 and the state census giving it a population of approximately 42 000 in 1925. Assuming a reasonable rate of future growth, comparable with that in the past and with various other cities within a close geographical radius, larger in size but similar in types of industry, the city should have a population of approximately 80 000 in 1950.

Water Supply System. The first water supply was furnished by the Chicopee Water Company from Abbey Brook in 1877, the city acquiring this system and that of the Willimansett Water Company in 1893. The Cooley Brook system with Mortin Brook was constructed in the same year while the Fairview system, consisting of wells and a pumping station, was built in 1909. Water has also been purchased from the city of Springfield when the other supplies proved inadequate.

The main source of supply, however, has been the Cooley Brook system supplemented by that of Mortin Brook. This source consists of a small reservoir on Cooley Brook, located about three-quarters of a mile above the Chicopee River, Mortin Brook being a tributary. The drainage area of Cooley Brook, as determined at the time of construction of the supply, is 4.55 sq. miles and that of Mortin Brook 0.35 sq. mile, giving a total of 4.9 sq. miles for the two streams. A low earthen dam with concrete core wall has been constructed across each stream, providing a small amount of storage. The dam on Cooley Brook was built in 1913 after the failure of the original dam constructed in 1893 and has a length of 165 ft. and a height of 13 ft. above the original stream level. The capacity of the reservoir on Cooley Brook is approximately 3 million gal., with an area of water surface of approximately three acres. The upper portion of the reservoir basin, flooded when the dam was built in 1913, was not cleared of stumps and vegetation, and this at times has caused considerable color in the water.

*Of Morris Knowles, Inc., Engineers, Pittsburgh, Pa.

Water is carried from the reservoir to the pumping station through two 16-in. pipe lines approximately 2 400 ft. in length and discharges into a settling basin having a capacity of approximately 200 000 gal.

The pumping station is a brick structure situated on Fuller Road and houses pumping equipment consisting of two motor-driven centrifugal units with capacities of 5 m.g.d. and 7 m.g.d., respectively.

Water is discharged through 16-in. and 20-in. pipe lines to the storage tanks consisting of two standpipes, one having a capacity of approximately 1 million gal. with its top at about elevation 300 and the other having a capacity of 1.9 million gal. with its top at about elevation 370. The smaller tank is no longer in service, due to its low flow line elevation, while the second tank, constructed in 1920, was one of the largest steel tanks to be built at that time.

The distribution system consists mostly of cast-iron mains, although a few cement-lined wrought-iron pipes are still in use. Sizes of lines range from two to twenty inches and pressures range from a maximum of approximately 125 lbs. per sq. in. in the lower part of the city to 50 lbs. per sq. in. in the higher section.

The Fairview system was discontinued in April, 1925, because of the poor quality of water and the excessive cost of maintaining the supply.

Report on New Supply. Realizing the necessity of developing a new source from which an adequate supply of water could be secured, the city officials authorized a study and investigation of the various supply projects available for providing the increasing requirements of the city. As a result, the engineering organization of Morris Knowles, Incorporated, submitted a report under date of January 20, 1926, recommending the development of Cooley Brook by means of an impounding dam and reservoir, this being the most economical and suitable for present development. Filtration was not considered necessary, under present conditions. Other sources of supply studied were Fuller Brook, Langewald Pond, Muddy Brook, the Chicopee River, the Connecticut River and the Water Works of the city of Springfield. Exclusive of the latter supply, which is already purified, all other supplies would have to be filtered to insure a safe quality of water.

The studies indicated that it would be unreasonable to expect for an extreme dry year a dependable yield of more than approximately 800 000 gal. per sq. mile per day under conditions at Cooley Brook, or a total of 3.5 m.g.d. In the absence of stream gaging records, these conclusions were reached from weir-reading records of several years ago, in addition to the fact that the present supply has been adequate in the past, to meet with the limited storage available, the needs of the city by careful and efficient operation.

It was found necessary to provide from storage all water in excess of 2 m.g.d. or 1.5 m.g.d. in order to supply an average daily flow of 3.5 m.g.d. throughout the year. On this assumption, a storage reservoir having a capacity of approximately 135 million gal. was required to provide for a

period of three months during dry spells, when the flow of the stream is insufficient to meet the daily demands.

The most economical site on Cooley Brook for a dam and a storage reservoir was found near the upper end of the existing basin where the drainage area is approximately 4.5 sq. miles.

New Work.

General Description. The new supply works, as designed, consist of a dam and a storage reservoir with water surface at elevation 170, i.e., 40 ft. above the elevation of the normal water surface in the old reservoir. It was found, however, upon running accurate topography of the entire area below contour 170, that the storage capacity of the reservoir would be 145 million gal. instead of 135 million gal., as previously computed. A normal water elevation of 170 was, however, maintained for the design, giving an additional storage of 10 million gal. to compensate for any discrepancies in the assumption of the safe yield of the stream.

The dam is of embankment construction forming a reservoir with a surface area, at normal water level, of approximately 30 acres and a maximum depth of 42 ft. A 24-in. supply line is provided to connect the new reservoir with the existing supply line at the gatehouse of the old dam. The length of this line is approximately 1 100 ft.

Provision has been made for eliminating the present settling basin at the pumping station, in order to take advantage of the additional head of water resulting from the increased height of the normal water surface. This, with the reservoir full, will amount to approximately 40 ft. and should appreciably decrease the cost of power for pumping.

Investigation. Due to the nature of the material available for embankment, the absolute necessity was realized for a careful investigation of the underground strata, for adapting the design to meet the particular conditions existing at the site and for deviating from common practice in earth dam design. There being little precedence governing the construction of a dam under conditions similar to those found at this site, no expense was spared in securing reliable information for the basic design. In an ordinary design, the core wall extends to an impervious stratum such as bedrock or clay and generally has an abundance of impervious material available for embankment. In this case, however, the underlying strata, to a depth of approximately 90 ft. (location of bed rock), consist of gravel, sands and silts, some of which are quite pervious.

In order to obtain a clear conception of the character and composition of the underground strata at the dam site, seven test pits were excavated on the slopes of the valley between the bottom and the proposed flow line at elevation 170, with depths ranging from 3 to 17.5 ft. Five test holes with a maximum depth of 91 ft. were drilled from the bottom of the various test pits, with the exception of one which was started from the bottom of the valley. Test borings were made by a local well-driller by driving a casing

and removing the strata from the casing as the work progressed. Samples were taken with a tube sampler at every change in soil stratification from a depth in advance of that to which the casing had been driven and were kept in glass bottles with metal screw caps. Two auger borings, one on each slope, were made to a depth of 30 ft. at elevation approximately 210, or 40 ft. above the proposed flow line. (See Fig. 1.) Samples of the soil thus secured from the test borings, as well as samples taken from the test pits, were analyzed in the laboratories of the Massachusetts Institute of Technology under the direction of Dr. Charles Terzaghi, Professor of Soil Mechanics, who also explored the dam site and made personal inspection of the test pits.

The chief object of the soil tests was to establish a basis for estimating the expected losses of water due to percolation around and under the proposed structure and for judging the suitability of the available materials for the embankment. Due to the exceedingly variable character of the material, a great many data were required for estimating the average permeability of the strata. Therefore complete mechanical analyses and determinations of the voids in a loose and in a compacted state were made of all samples obtained from the test pits, sixteen in number, and of representative samples obtained from the test borings, twenty-three in number. In addition, permeability tests were made upon typical samples selected from those obtained from the test pits, namely, six in number.

From the results of the soil tests, a geological profile of the dam site was constructed, and this also served as a permeability graph of the underground. The outstanding features of the materials forming the underground strata at the dam site are the exceptionally low uniformity coefficients and the almost complete absence of clay. The uniformity coefficients range between 1.72 and approximately 4. The materials consist essentially of quartz grains intermingled with some light and dark mica.

The effective size of most of the samples ranged between the limits of 0.02 and 0.06 mm. All of these properties are characteristic of sands that are apt to turn into quicksand whenever the hydraulic conditions tend to produce such an effect.

In the drill hole started from the bottom of the valley, bedrock was encountered at elevation 41, or approximately 90 ft. below the surface of the stream bed. This rock consists of a dark red, fine-grained sandstone (Longmeadow sandstone), characteristic of the territories coinciding with the west rim of the Connecticut Valley. Artesian flow came up through the casing and has now been running for more than a year without any decrease in rate. This fact would seem to indicate that the 40-ft. layer of dark gray silty sand covering the bottom is continuous and almost impermeable.

Design of Dam. Considering the character of the underground strata and the materials available for embankment, a core wall type of dam combined with a cut-off consisting of steel sheet piling seemed to present

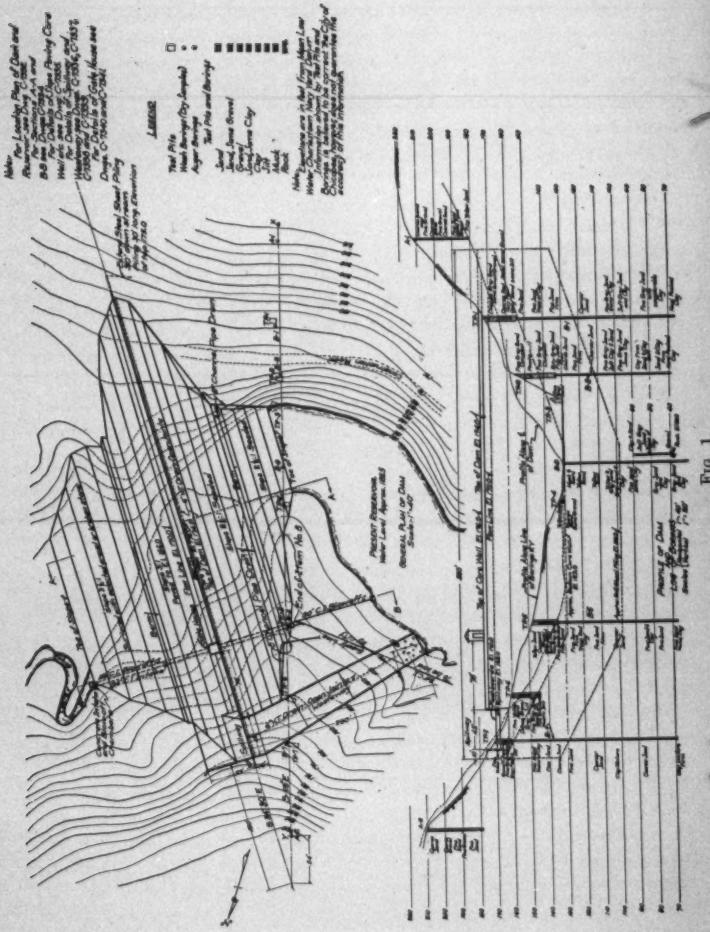
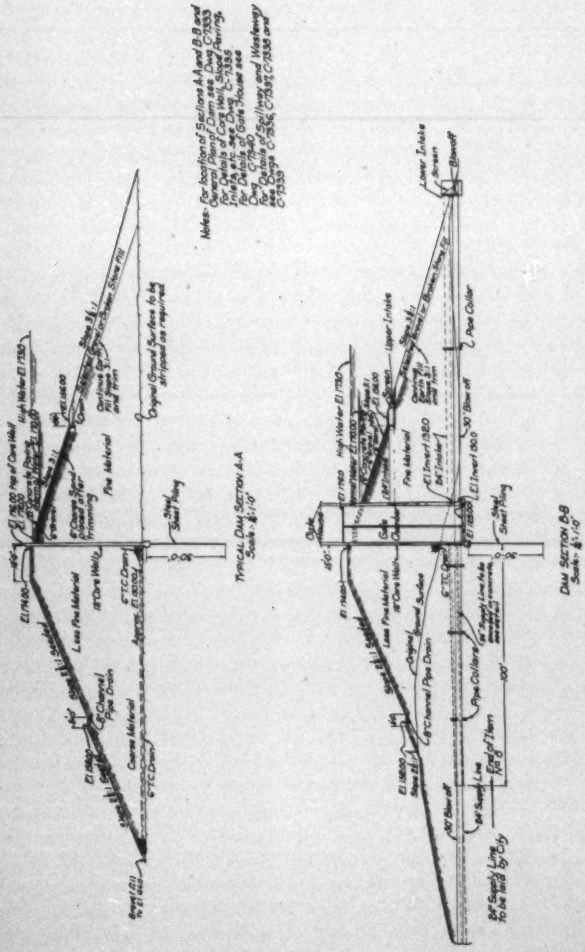


FIG. 1.


Notes:- For location of Sections A-A and B-B and General Plan of Dam see Dwg. C-7333
For Details of Core Wall, Slope Paving, Inlets, etc see Dwg. C-7335
For Details of Gate House see Dwg. C-7340
For Details of Spillway and Wastewaty see Dwgs. C-7336, C-7337, C-7338 and C-7339
TYPICAL DAM SECTION A-A
Scale: 1/4"=1'-0"
DAM SECTION B-B
Scale: 1/4"=1'-0"
Original Ground Surface to be stripped as required
Fine Material
Coarse Material
Less Fine Material
Steel Piling
Lower Intake
Upper Intake
Screen
Blowoff
Pipe Collar
Pipe Collars
Gate Chamber
Gate House
High Water El 1730
Original Ground Surface
8" Channel Pipe Drain
6" T.C. Drain
18" Core Wall
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El 0.00

FIG. 2.

the more satisfactory solution of the problem; the core wall to prevent the loss of water through the embankment and the steel sheet piling to reduce to a minimum the seepage of water underneath the dam.

The dam is an embankment structure, consisting almost entirely of sand and a very small percentage of silt and loam, approximately 550 ft. long at the top, with a maximum height above the bed of the stream of approximately 48 ft. A reinforced concrete core wall extends the entire length of the embankment near the center and projects beyond the ends into the adjacent hillsides approximately 25 ft. The concrete core wall has a maximum vertical height of approximately 50 ft., the base being placed at the ground water level in order to avoid pumping, and the top approximately 2 ft. above the elevation of the downstream embankment. (See Fig. 2.)

The downstream embankment has a top width of 15 ft. and a $2\frac{1}{2}$:1 slope throughout its length, with a 5-ft. berm at elevation 152. The downstream toe consists of a gravel fill for a vertical height of approximately 8 ft. to prevent sloughing of the slope from seepage through the embankment material and from any wave action of the water in the lower reservoir.

The upstream embankment has a top width of approximately 6 ft. and a 3:1 slope with a 5-ft. berm at elevation 156.

The spillway is a reinforced concrete structure built entirely in cut and located at the extreme north end of the dam. The spillway has a total length along the center line of approximately 225 ft., a width at the crest of 45 ft., a width at the lower end of 25 ft. and is constructed in four steps.

At the extreme lower end of the spillway, steel sheet piling, capped with a 24-in. x 24-in. concrete block, has been driven to a depth of 20 ft. for the bottom width of the structure and extending out from the walls 25 ft. on each side, in order to prevent any possible undermining of the lower section.

Twelve 18-in. x 18-in. concrete piers, 4 ft. high, have been built on the floor of the lower section, to decrease the velocity of the water and to aid in preventing erosion at the end of the spillway. A 6-in. vitrified-tile drain with open joints and a broken stone filter extend the entire length of the spillway. The spillway has a capacity of 400 sec. ft. per sq. mile, the concrete crest being at elevation 168, or 8 ft. below the top elevation of the core wall. This provides for a maximum effective depth over the crest of 6 ft., assuming an allowance of 2 ft. for freeboard. Provision has been made for the installation of flashboards 24 in. high, so that the increased capacity resulting from the additional 2 ft. depth of water over the entire surface area may be secured with the same relative height of dam. The flashboards will raise the effective crest of the spillway to elevation 170 and will be supported by mild steel pins $1\frac{1}{2}$ in. in diameter, spaced 2 ft. apart and grooved so that the pins will fail with a 2-ft. head of water over the top of the boards.

A 30-in. cast-iron blow-off pipe extends the entire width of the em-

bankment with invert elevation at the gatehouse of 130. Two intakes — one at elevation 132, the other at elevation 153 — are connected with the gate chamber by means of 24-in. cast-iron pipe lines. One 24-in. cast-iron supply line extends through the downstream embankment and continues to the old gatehouse. The blow-off and supply pipe lines underneath the downstream embankment are encased in concrete with adequate concrete cut-off collars.

The gate chamber is a reinforced concrete structure located upstream from the core wall, one of its walls being formed by the core wall. The gate chamber houses two movable fish screens, which slide along either side of a division wall. These are raised and lowered from the gatehouse superstructure. Two 24-in. sluice gates and a 30-in. gate valve are also housed in the gate chamber. The gatehouse superstructure is built of brick and houses the operating stands for sluice gates and the valve and lifting mechanism for the fish screens.

One of the most difficult features of the dam site was the considerable permeability of the strata which compose the underground and the slopes. Due to these conditions, a continuous row of steel sheet piles, 30 ft. long, was driven for the full length of the dam. Because of the nature of the underground, the sheet piles will practically intercept the percolation through the strata located below the bottom of the dam. At the north end of the dam seepage conditions were rather favorable on account of the peculiar topography. The dam was located so that the major portion of the seepage percolating around the north wing will come out of the slope of the valley at a distance of approximately 100 ft. downstream from the toe. At the south end of the dam the steel sheet piling was extended approximately 30 ft. downstream, the bottom being at elevation 145, so as to carry the seepage water to a point outside the embankment.

Due to the physical characteristics of the available material for making the embankment, there was the danger that these materials might flow out whenever the state of saturation combined with an hydraulic gradient directed towards a free surface. Such hydraulic conditions are apt to occur in the upstream part of the embankment when the water level in the reservoir is being rapidly lowered and in the downstream section of the embankment due to water seeping from beneath the dam into the embankment.

The first condition was perhaps the more serious, due to the necessity of using the least permeable material available for the upstream section. The less the permeability of the material, the greater is the hydraulic gradient with which the water flows out of it when the water level in the reservoir is being lowered at a given speed. In order to prevent the flowing out, or sloughing away, of the embankment materials at such times, the slope was made 3:1 and was protected with a concrete paving 6 in. in depth, underneath which was placed a graded filter consisting of 6 in. of gravel or broken stone and 6 in. of coarse sand. It was necessary to separate the layer of gravel from the fine sand in the dam proper by a layer of very coarse

sand, in order to prevent the fine material from working its way into the voids of the gravel and clogging the filter; the material used in the upstream section was perfectly clean and had little, if any, cohesion. As the concrete slope paving was placed only on the upstream slope between the top of the embankment and the berm at elevation 156, it was necessary to provide a bearing for the lower edge of the paving slabs consisting of a concrete beam, buried in the berm, approximately 21 in. wide and 3 ft. deep. Weep holes, 6 in. in diameter, were placed at regular intervals through the retaining curb, or bearing beam, for conveying the seepage water from the 12-in. broken stone collecting filter, separating the beam from the embankment, to points outside of the dam.

An open space of approximately 2 in., filled with asphalt, was left between the core wall and the paving, so as to compensate for any movement of the paving slabs caused by the settling of the upstream embankment. The paving slabs are approximately 20 ft. square and are reinforced with wire mesh. The concrete paving also serves as a protection against wave action. The slope below the berm is protected by means of a layer of selected gravel and broken stone fill approximately 18 in. deep at the berm and 5 ft. at the toe. (See Fig. 3.)

The condition in the downstream embankment, due to seepage water passing from beneath the dam into the embankment, was taken care of by using a material which is more permeable than the fine-grained sand composing the major portion of the side slopes. In this connection, the location of the dam, due to the peculiar topography, had a considerable bearing. At the original location selected for the dam site there was a flat promontory which diverted the creek toward the south slope, this being very steep at this point. The promontory contained a layer of gravel from two to three feet in thickness, extending from the flow line down to the bottom of the valley. As this bed of gravel will undoubtedly collect most of the seepage water entering the promontory, the dam was located in such a manner that the water would drain away at a point outside of the downstream toe.

On the south slope, the highly permeable material is confined to elevations higher than approximately 155, and steel sheet piling was therefore used to divert the flow coming from the strata to a point outside of the dam.

The upstream section of embankment was made out of what may be called a very coarse silt (effective size of about 0.02 mm.) with a coefficient of permeability below 35.10^{-4} cm. per sec. This material consisted of a layer of "very fine reddish sand" below elevation 145 and "very fine gray sand" between elevations 145 and 160, both found in the north slope above the dam site. This material had all the characteristics of a material that would become a typical quicksand under the proper hydraulic conditions. The upstream section communicates freely with the water in the reservoir through its base and slope and is subject to complete saturation when the reservoir is full.

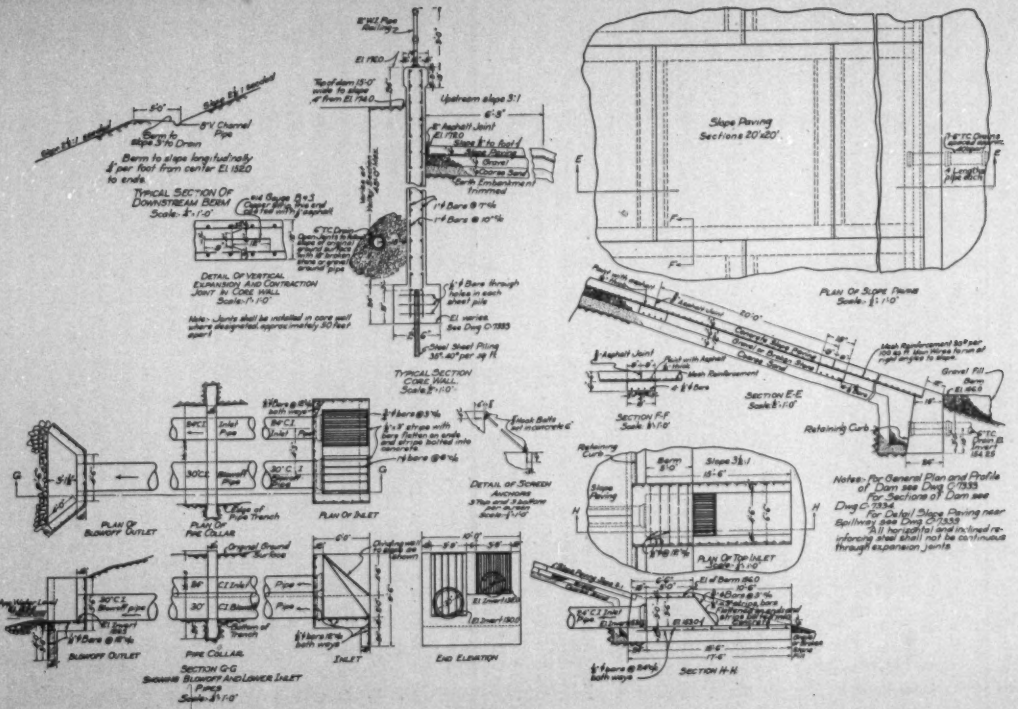
Slope Paving
Sections 20' x 20'
PLAN OF SLOPE PAVING
Scale: 1" = 10'
SECTION E-E
Scale: 1" = 10'
SECTION F-F
Scale: 1" = 10'
Retaining Curb
Gravel Fill
Berm
El. 66.0
Asphalt Joint
Mesh Reinforcement
Concrete Slope Paving
Coarse Sand
Notes:- For General Plan and Profile of Dam see Dwg C-7333
For Sections of Dam see Dwg C-7334
For Outlet Slope Paving near Spillway, see Dwg C-7339
All horizontal and inclined reinforcing steel shall not be continuous through expansion joints
TYPICAL SECTION OF DOWNSTREAM BERM
Scale: 1" = 10'
Berm to slope 3:1 to Drain
8"V Channel Pipe
Berm to slope longitudinally 1/4" per foot from center El 1320 to ends
DETAIL OF VERTICAL EXPANSION AND CONTRACTION JOINT IN CORE WALL
Scale: 1" = 10'
Note:- Joints shall be installed in core wall where designated, approximately 30 feet apart
TYPICAL SECTION CORE WALL
Scale: 1" = 10'
Top of dam 15'-0" wide to slope 4' from El 1340.0
Upstream slope 3:1
8" Asphalt Joint
El 1320
Slope 3/4 to Roof
Gravel
Coarse Sand
Earth Embankment trimmed
#4 Bars @ 7 1/2"
#4 Bars @ 10"
#4 Bars through holes in each sheet pile
El varies, See Dwg C-7335
Steel Sheet Piling 30'-40" per sq ft
PLAN OF BLOWOFF OUTLET
PLAN OF PIPE COLLAR
PLAN OF INLET
DETAIL OF SCREEN ANCHORS
3 Bars and 3 bolts per screen
Scale: 1" = 1'-0"
Steel Bolts set in concrete 6'
BLOWOFF OUTLET
PIPE COLLAR
INLET
END ELEVATION
SECTION G-G
SHOWING BLOWOFF AND LOWER INLET PIPES
Scale: 1" = 1'-0"
PLAN OF TOP INLET
Scale: 1" = 1'-0"
SECTION H-H
Retaining Curb
Slope Paving
Berm
Slope 3 1/2:1
El of Berm 66.0
#4 Bars @ 7 1/2" both ways
#4 Bars @ 6" both ways

FIG. 3.

In contrast to this, the downstream section of the dam is to be kept practically dry, and a material as permeable as possible was therefore used. The material selected for this section was coarser than the average slope material and that located below the base of the dam. It was a fine sand (effective size of about 0.2 mm.) with a coefficient of permeability of more than 350.10^{-4} cm. per sec. This material was secured from the "coarse gray sand deposit" located on the north slope above elevation 160, immediately below and to the north of the dam site. The seepage water flowing around the ends of the dam and underneath the steel sheet pile cut-off wall will pass from a less permeable material into a more permeable one and drain away.

The specifications required that the embankment be placed in successive layers not to exceed 6 in. each, the surface to be kept leveled, slightly moistened, if necessary, and rolled either with a corrugated roller or with a caterpillar. Prior to placing the embankment, it was necessary to remove completely the deposit of black muck in the valley section underneath the area because of its excessive compressibility. This deposit extended to a maximum depth of 4–5 ft.

The upstream and downstream sections of the dam are separated from each other by means of a reinforced concrete core wall, designed so as to combine flexibility with bending resistance. Since a thin core wall adapts itself more readily to unequal settlement within the body of the dam than a thick one, the core wall was made 12 in. thick. Double reinforcement was provided so as to utilize the strength of the concrete and steel to their limit in case the wall tends to warp. The reinforcement on each side consists of 1-in. steel bars spaced 7 in. on centers in a vertical direction and 10 in. on centers in a horizontal direction.

The steel sheet pile cut-off wall is firmly tied into the concrete core wall by means of three ½-in. steel bar anchors through each pile. The anchors are in turn embedded in the base of the core wall which is 2 ft. 6 in. wide by 24 in. high. The steel sheet piles extend into this base 21 in. and provide a tight and firm connection between the two structures.

Prior to the formation of the Cooley Brook valley, the underground of the valley bottom carried an overburden of at least 100 ft. of sedimentary material. As a result, the construction of the embankment should not cause any appreciable compression of the underground, and there is little or no danger, therefore, of the core wall cracking due to unequal settlement of the foundation. Expansion joints, however, have been provided in the core wall at approximately 50 ft. intervals to prevent the formation of temperature and shrinkage cracks in the concrete. Positive water stops consisting of No. 14 B. & S. gage copper strips, approximately 22 in. wide, have been placed the entire length of all vertical joints in the core wall for preventing leakage at such places.

Because of the nature of the deposit over the flat area of the valley immediately upstream of the dam site, all vegetation and the black muck

or silt deposit were removed below contour 140. The entire area flooded by water was also cleaned of all trees, stumps and brush.

The weakest link in the entire project lies in the extent of the water losses through seepage around the wings of the dam at full reservoir. These losses may amount to as much as 180 000 gal. per day, but, due to the geological character of the strata located on both sides of the dam, there was no chance for appreciably reducing these losses by extending the row of sheet piles into the hillsides. There is, however, the possibility that the losses due to seepage will gradually decrease by silting up of the valley slopes. In order to measure these losses due to seepage, we have recommended the construction of a permanent measuring weir across the brook at a point above the flooded area.

Construction Methods and Results. Excavation of test holes and the removal of trees, stumps and brush from the flooded area were carried out by the Water Department under the supervision of Mr. John F. Sullivan, Superintendent.

Test borings were carried out by G. E. Montague, an experienced well-driller of West Springfield, Mass.

All pipe, fittings, valves, etc., required were purchased directly by the Water Department.

Bids were received for the construction work on August 19, 1926, a total of six proposals being secured. These ranged in price from approximately $180 000 to approximately $280 000. The contract was awarded to the Sanders Engineering Company of Portland, Me., on September 22, 1926, and actual construction operations started immediately thereafter.

Because of the condition of the roads leading to the dam site, considerable work and expense were necessary to make them passable for hauling the heavy equipment and materials.

The stationary plant consisted of a cableway, approximately 900 ft. between A-frames, erected directly over the center line of the core wall, with operating machinery on the south slope, and of a complete concrete plant located on the south hillside above the end of the core wall. Material hoppers were constructed at sufficient elevation above the mixer to permit the dumping of the sand and aggregate into batch cars which in turn were dumped into the mixer. The concrete materials were hauled to the site in dump trucks, the sand and aggregate being dumped directly into the hoppers and the cement being placed in a house built at the same elevation as the top of the material hoppers.

One of the main construction problems which gave considerable concern to everyone was the stream protection to be provided during the progress of the work. The city was almost entirely dependent for its supply of water from the yield of Cooley Brook above the dam site. As construction operations were carried out immediately upstream of the flooded area of the old dam, it was necessary not only to continue to permit the discharge of the stream through the dam site into the old reservoir, but to take every

possible precaution to prevent contamination and roiling of the water. One of the first precautionary measures taken by the Water Department was the installation of liquid-chlorine apparatus in the pumping station to treat all of the water from Cooley Brook with a chemical germicide before discharging it into the distribution system.

In addition to the precautionary measures against contamination and for maintaining the city's supply, it was necessary for the contractor to make provisions for protecting the construction work against flood flows of the stream. As comparatively little work could be done adjacent to the stream without roiling of the water, one of the first operations consisted in excavating for and laying the 30-in. blow-off, the lower 24-in. intake and the 24-in. supply lines underneath the embankment. Because of the seepage from the adjacent hillside into the trenches and the constant boiling of the sand in the bottom, it was necessary to support all three lines on pile bents.

A small cofferdam was constructed approximately 50 ft. upstream from the inlet end of the blow-off and intake pipes at a comparatively narrow place in the valley. The cofferdam was connected with the intake and blow-off lines by means of a wooden flume. This stream protection work served adequately during the entire construction period. Early in the winter of 1927, the 24-in. supply line between the new and old dams was laid and connected into the gatehouse at the old dam, after which water was supplied to the city directly from the cofferdam, and the old reservoir was, for the most part, abandoned.

Excavations for the core wall and pipe trenches were made with a caterpillar drag line which was used also for stripping the area underneath the embankment and that in the valley section below Contour 140. Stripping was also done with a caterpillar steam shovel, four caterpillar dump trucks being used to convey the material to the top of the north hillside where it was deposited far enough back to prevent washing into the reservoir.

As soon as a sufficient length of core wall trench was completed, driving of the steel sheet pile cut-off wall was started. The piles were driven with a steam hammer supported from the cableway, steam being furnished from a boiler plant located at the dam site in the valley. Considerable difficulty was experienced in driving the steel sheet piles because of the compactness of the underground material. Jetting had to be resorted to, in order to make satisfactory progress and secure a reasonably straight line.

The core wall was built in 50-ft. sections approximately 12 ft. in height ahead of the placing of the embankment. The concrete was placed by means of a hopper bucket supported from the cableway so that it could be moved along the section being poured and the material deposited in the 6-in. layers required by the specifications. This method produced excellent results with unusually few honeycombed spots, considering the thin wall and the comparatively large amount of steel reinforcement.

The upstream and downstream sections of the embankment were

placed at the same time by means of four caterpillar trucks, loaded at the respective borrow pits by a steam shovel, and by a drag line equipped with shovel attachment. The upstream embankment material was secured from the north hillside above the dam, while that for the downstream section was likewise secured from the north slope, but at a considerably higher elevation slightly below and to the north of the site. The length of haul for each was comparatively short. Two eight-hour shifts were worked in placing the major portion of the embankment,— one shift placing the materials on the downstream section, and the other on the upstream section, both sections being kept at approximately the same level. This resulted in building the embankment as fast as the construction of the core wall would permit and appreciably speeded up the progress of the work.

The embankment materials were placed in thin layers and were kept leveled by scrapers operated by two caterpillar tractors. It was found unnecessary to roll the embankment materials in either section to secure the desired compactness, as the constant running on the surface with the caterpillar trucks and tractors, while leveling, produced better results than could be secured with a roller. The caterpillar movement of the trucks and tractors caused a vibrating or shaking of the materials already placed and apparently eliminated, to a large degree, subsequent settlement. Elevations taken at short intervals during and after the placing of material showed no appreciable settlement even in the upstream section after the embankment became saturated to over one-half its depth.

In order to insure the securing of the kind of material desired, for both the upstream and downstream sections of the embankment, several tests were run in the field each day to obtain an approximate conception of the coefficient of permeability of the borrow pit materials. For this purpose, a device consisting of a simple tank made out of sheet tin, an irrigator for feeding the tank and a set of four thick glass tubes was used. The bottom of each glass tube was provided with a brass wire mesh stretched across the bottom and wired to a brass ring.

The procedure in testing each sample was first to dry it on a stove and then to place the sample into the glass tube in layers, two centimeters thick, until the cylinder was completely filled. Each one of the layers was compacted by dropping a cylindrical pestle, made out of hard wood with a diameter of 1¼ in. and a weight of 150 grams, ten times from an elevation of 4 in. The tank in the meantime was filled with water from the irrigator, the water passing over the crest of the overflow provided and the excess draining away, thus maintaining a constant level in the tank. As soon as the cylinder was filled with a sample, the brass sieve was wet with a moist cloth and the cylinder placed on an immersed support in the tank.

Care had to be taken while lowering the cylinder down to the surface of the water to keep it in a slightly inclined position so that the air had a chance to escape laterally. As soon as the base of the glass cylinder touched the surface of the water, the water rose by capillary action within the sam-

ple as shown by the color turning dark. The smaller the permeability of the sample, the slower occurred the upward movement of the moisture. By observing the position of the level of the capillary water after 5, 10, 20, and 30 minute intervals and plotting the data thus obtained, it was possible to estimate roughly the degree of permeability of the material.

As the upstream embankment progressed, the broken-stone and selected-gravel protecting-layer along the slope below the berm was placed and the water allowed to rise with the embankment. This resulted in impounding a comparatively larger quantity of water for use during the summer months than had been possible heretofore in the old supply works and gave the city the advantage of the new work before it was completed. As a result, water at this time has been impounded approximately to elevation 160, giving a maximum depth in the basin of 32 ft., this being equivalent to a storage of 65 million gal.

Because of the satisfactory methods used in placing the upstream embankment, thus producing a very compact mass, the concrete slope paving above the berm was placed approximately six weeks after the completion of the embankment. The many heavy rains during this period and the complete saturation of the lower portion of embankment, due to impounding the water back of it, produced no noticeable settlement, and it was therefore considered safe to place the slope paving at that time instead of allowing the embankment to settle for a considerable period as is customarily done. (See Fig. 4.)

The major items in the contract consisted approximately of the following quantities and contract prices:

Stripping	30 000 sq. yds. @ $0.20 per sq. yd.
Excavation	9 500 cu. yds. @ $1.25 per cu. yd.
Sheet steel pile cut-off wall	346 tons @ $94.00 per ton
Rolled embankment	64 000 cu. yds. @ $0.80 per cu. yd.
Concrete masonry	1 440 cu. yds. @ $25.00 per cu. yd.
Concrete masonry	860 cu. yds. @ $22.00 per cu. yd.
Steel reinforcement	405 000 lbs. @ $0.05 per lb.
Gravel and broken stone fill	3 600 yds. @ $2.25 per yd.

The construction work upon the project was completed on September 8, with the possible exception of such minor items as seeding and final cleaning up of the site.

The equipment and plant used by the contractor were well adapted for the work. Because of the large amount of water seeping from the adjacent hillside, the bottom of the valley was wet and soft and of a quicksand character. Therefore, movable equipment other than that of the caterpillar type would have proved impractical and uneconomical. The tractor drag line with shovel attachment was adapted for economical and satisfactory use, not only for the excavating, stripping and placing of the embankment, but also in the handling of pipe, rolling of the slopes, placing of loam and placing of the sand and gravel filter underneath the slope paving.

Fig. 4.

The concrete plant was ideally located to operate with a minimum amount of labor and to facilitate the accurate measurement of the materials used and the mixing of concrete. The cableway proved to be a useful piece of equipment and not only reduced the amount of labor to a minimum, but also materially increased the rate of progress and made it possible to carry out the work to an economical completion. This was true in the driving of the steel sheet pile cut-off wall and in the placing of the concrete in the core wall, slope paving and spillway. It may be said that the entire plant and equipment were well planned and selected for the carrying out of the work in accordance with the intent of the contract and specifications and to a satisfactory completion of the work.

The cost of the entire project will amount to approximately $250 000.

A word of commendation is due the Superintendent of the Water Department on the manner in which the supply of water to the city was maintained during the construction period. At no time was there a shortage of water, the supply being furnished entirely from Cooley and Mortin brooks and few complaints being received due to discoloration or inferior quality.

Personnel. The project was carried out in coöperation with Dr. Michael I. Shea, Mayor, the Board of Water Commissioners composed of: James J. Jennings, Chairman; Benjamin Simpson, Cornelius A. O'Brien, (resigned in April, 1927) and Ernest Dauplaise, who succeeded Mr. O'Brien; and John F. Sullivan, Superintendent of the Water Department.

The construction work was in personal charge of Mr. E. E. Sanders, President of the Sanders Engineering Company of Portland, Maine.

Plans and specifications were prepared and construction work was supervised by Morris Knowles, Incorporated, of Pittsburgh, Pa., under the direction of the author. Lyman C. Lovell was Resident Engineer.

Dr. Charles Terzaghi, Professor of Soil Mechanics at the Massachusetts Institute of Technology, was engaged in an advisory capacity in connection with the investigations, soil tests, designs and construction of the project.

CONTROL OF WATER SUPPLIES IN NEW YORK STATE AND LAWS RELATING THERETO.

BY C. A. HOLMQUIST.*

[*Read September 13, 1917.*]

The laws relating to public water supplies vary considerably in different States. In some States the laws place the jurisdiction over water supplies almost entirely under the State Boards or Departments of Health. In other States the control over public water supplies is exercised by two or more different departments or commissions. New York falls under the latter group. In general, the State Department of Health in New York has jurisdiction over the sanitary quality of existing water supplies under the Public Health Law, and the Division of Water Power and Control of the State Department of Conservation has jurisdiction over approving new or additional sources of supply under the Conservation Law. No state approval is required of plans for the installation of water purification or filtration plants for existing supplies.

These two departments or branches of the state government exercising control over public water supplies in New York have always worked in close coöperation and there has been no overlapping of authority or duplication of efforts in their work. The operation of the Conservation Law with respect to the approval of projects for new or additional public water supplies was set forth in considerable detail in the excellent paper read before this Association on September 15, 1915, by Mr. Russell Suter, then Assistant Civil Engineer of the Conservation Commission and now Executive Engineer of the Division of Water Power and Control of the New York State Department of Conservation, and will therefore not be reviewed in this paper, especially as there has been no material change in the Conservation Law relating to this subject since that time.

Although the State Board of Health in New York was established and organized in 1880 under legislative enactment known as Chapter 322 of the Laws of 1880, it was not until 1885 that the Board of Health was given any specific control over public water supplies. In that year, the Legislature passed an Act authorizing the State Board of Health to enact rules and regulations for the protection from contamination of any or all public supplies of potable water and their sources within the State. Such regulations had the force of law when approved by the County Judge of the county in which the supply was located. This law has been, and still is, construed as being permissive and not mandatory, and it has not been the policy of the State Health authorities to enact rules and regulations without the approval and consent of municipalities or water companies

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except in cases where the Division of Water Power and Control has approved projects for additional water supplies on the condition that the municipality or water company shall have suitable rules and regulations enacted.

The original law with reference to the enactment of rules and regulations provided among other things that a penalty not exceeding $200 might be imposed for a violation or non-compliance with the rules and regulations, if the violation related to a permanent source of contamination of the supply. This law also contained the provision that "Every person who shall wilfully violate or refuse to obey any rule or regulation made and published by the State Board of Health, and approved, pursuant to the provisions of this Act, shall be guilty of a misdemeanor, and on a conviction thereof, shall be subject to a fine, or imprisonment, at the discretion of the court, such fine not to exceed three hundred dollars, ($300.00), nor such imprisonment six months." This provision of the law was evidently found to be too drastic and was soon repealed.

A new clause was inserted in the law a little later, however, making a temporary source or act of contamination of a water supply, protected by rules and regulations, a misdemeanor punishable by a fine not exceeding $200 or imprisonment not exceeding one year, or both, thus making a marked distinction between a permanent and a temporary source or act of contamination.

The law with reference to the enactment of water rules has been amended from time to time and is now known as Sections 70, 71 and 73 of the Public Health Law. It no longer requires the approval of a county or supreme court judge to make the rules enacted by the State Commissioner of Health effective. It has also been so amended that the water supply authorities of New York City may now make rules and regulations subject to the approval of the State Department of Health for the protection from contamination of the city's sources of public water supply within the State. In other respects it is substantially as originally enacted.

The procedure outlined by the law for the abatement of violations, except in the case of New York City, requires joint action by the State Commissioner of Health and the local health and water supply authorities. The cost of abatement of violations of the rules relating to a permanent source of contamination must be borne by the municipality or water company owning the supply for whose benefit the rules were enacted.

Concerning the obligation of water corporations or departments to provide for cost of, or for the making of changes or improvements demanded by the rules, but not specifically mentioned in Section 73 of the above law, the State Attorney General has rendered an opinion from which the following is an abstract:

"In my opinion the proper and only lawful construction which can be placed on Section 73 of the Public Health Law is that all damages and injury to the owner of any property affected by changes required to be made to

comply with the rules of the Department of Health must be ascertained and paid prior to the taking possession of the property and is a prerequisite to the enforcement of said rules in all cases except such as are a nuisance in and of themselves, in which case the Department of Health would have power and authority outside of Sections 70, 71 and 73 to abate the same. Any other construction would, to my mind, render the law unconstitutional. In brief, I am of the opinion that the State Department of Health can make and promulgate rules regulating and controlling the use of premises surrounding the sources in all regards, and that a person violating any of those rules can be punished as provided by the penalties, but before such punishment can be inflicted, the corporation for whose benefit the rules are made and established must pay or tender to the owner of the property affected by the enforcement of such rules an amount equal to all damages for making the changes necessary."

If, therefore, a privy or cesspool or other possible source of contamination is maintained in a sanitary condition and is not overflowing, but is located closer to the stream or body of water from which a public water supply protected by rules is derived, than is permitted by such rules, the cost of removing such structure, or so changing it as to conform to the rules, must be borne by the owner of the water supply affected. If, on the other hand, the condition of such structure is such as to constitute a public nuisance or menace to health, or if it actually pollutes a water supply, action is then possible under other sections of the Public Health Law, and the owner of the structure must bear the expense of abating the nuisance.

The law also provides that, when the State Department of Health or the water supply authorities of New York City shall, for the protection of a water supply from contamination, make orders or regulations, the execution of which will require construction and maintenance of a system of sewerage or sewage disposal, or a change thereof in or for any hamlet or village, the municipality or corporation owning the water works benefited thereby shall, at its own expense, construct and maintain such system of sewerage and sewage disposal. Under this provision of the law and subsequent enabling acts, the City of New York has constructed and is operating on its Croton watershed sewage disposal works for Mt. Kisco, a village having a population of about 5 000. These works consist of settling tanks, sprinkling filters, intermittent sand filters and chlorination plant. It is also constructing, at the cost of nearly $375 000, a complete sanitary sewer system and sewage disposal works for the village of Tannersville on the watershed of its Catskill supply and is planning to construct a number of other sanitary sewerage systems in this area.

Before any rules and regulations for the protection from contamination of public water supplies are enacted, a detailed inspection of the watershed is made by one of the engineers of the Department in order to determine the sanitary conditions existing on the watershed, the nature and relative location of all possible sources of pollution and the probable cost and practicability of enforcing the rules. Although 135 public water supplies, nearly all of which are surface supplies, are now protected by rules and

regulations enacted by the State Commissioner of Health, no two sets of rules are exactly alike. Each set is individual in character and is drawn up to meet the local conditions. Consideration is given not only to the conditions on the watershed, but also to the degree of treatment or purification that is given to the water before it is delivered to the consumers.

It would obviously be inadvisable to enact rules and regulations that would prohibit the location of sources of pollution such as privies, cesspools, and barnyards so far from the water's edge of streams or watercourses draining thickly developed suburban districts that such structures could not be located on the properties affected, or so that the cost of the enforcement of the rules would be prohibitive. In such cases the minimum distance of such source of pollution from the water's edge must be made less than would generally be desirable. Rules have been enacted that allow privies within fifteen feet of the watercourse, provided such structures are equipped with removable water-tight containers and placed in water-tight compartments and provided the contents are removed and disposed of in such a manner as not to be a menace to the water supply. Furthermore, in such cases, special efforts are made by the Department to see that adequate purification or treatment of the water is provided and that the works are operated with care and efficiency.

As populations have increased, it has been found more and more difficult, even on smaller upland streams, to require that sewage of properties on watersheds of water supply sources be disposed of by means of cesspools, subsurface irrigation systems or other methods without overflow; so that most of the rules enacted within recent years have allowed the discharge into such water supplies of properly treated sewage effluent, the degree of treatment required depending again upon the nature and size of the stream, the distance from the intake and the efficiency of the water purification or treatment plant. Where water supplies are derived from large and grossly polluted rivers, like the Hudson River, which receives the raw sewage of approximately half a million people above the intake of the Albany supply, no attempt is made to protect such supplies by rules and regulations, and dependence must be placed almost entirely upon the efficiency of the water purification process.

Most of the rules enacted prohibit bathing, boating, fishing and ice-cutting on water supply reservoirs or, where the supplies are from relatively large lakes and streams, within certain limiting distances of the intakes. The courts in this State have held, however, that bathing in a water supply lake or reservoir by a riparian owner or his guests or friends is a legitimate use of such body of water and that he cannot be deprived of this right without compensation. (*Chester* v. *George*, Misc. N. Y., Vol. 59, p. 553.) It has been found, however, that the existence of rules has had a tendency to restrict bathing in water supply sources to a considerable extent.

The Public Health Council of the State has also enacted regulations in the Sanitary Code relating to public water supplies which have the force of

law and apply to all parts of the State except New York City. The most important of these regulations are those enacted in November 1925, which provide that no owner of a potable public water supply shall allow, after July 1, 1926, any physical connection between such supply and any other supply that is not potable, except that in the case of an existing cross-connection protected by double check-valves of approved type, such connection may be continued until July 1, 1928. Since these regulations were enacted, practically all prohibited cross-connections have been removed in most of the larger cities of the State, including Buffalo, Rochester and Syracuse. New York City has not allowed cross-connections for a number of years.

The activities referred to above are carried out under definite statutory requirements. The most important activity of the Division and one that has had the most far-reaching results in improvements of the public water supplies of the State is our general investigation and supervision over the sanitary quality of the 570 supplies of the State which has been carried on without any specific provisions of the Public Health Law or, until recently, without any definite enforceable authority. Approximately one half of the force of the Division is engaged in this work.

In these investigations the engineers of the Division periodically make detailed surveys of the watershed and reservoirs for the purpose of determining all possible sources of pollution. Detailed inspections are made of the pumping station and water purification plants, if any, to determine their capacity and efficiency of operation. Samples of the raw and treated water are collected and sent to the Division of Laboratories and Research of our Department for chemical and bacterial examinations. Studies are made of the field and laboratory examinations, and the results of these studies are incorporated in a report setting forth the results of the inspection and of the laboratory examination and making definite recommendations as to improvements to be made. These reports are transmitted to the water-works authorities and copies are sent to the local health officer and to the district state health officers, with instructions that the matter be followed up and that our recommendations be carried out. Reinspections are made as often as possible, especial attention being paid to those supplies which are not of an entirely satisfactory sanitary condition.

One man is engaged exclusively in the supervision of water filtration plants. During the past year, ten laboratories have been installed under his direction at filter plants which previously had no laboratory control. Monthly reports of daily results of the operation of water filtration and chlorination plants are received regularly from nearly all of the plants in the State, and these reports enable the Division to keep close supervision over these plants.

The reports on the daily results of operation of chlorination plants include a statement as to the amount of water treated per day, the serial number of the chlorine cylinder, the pounds of chlorine used per day, the

results of tests for free chlorine by the ortho-tolodin or starch iodide tests and the chlorinator setting in pulsations per minute or pounds per 24 hours. These reports also contain a column for remarks with the suggestion that data with reference to changes of cylinders of chlorine, or interruptions in the operation of the chlorinator, be noted. The reports of the daily results of the operation of water purification plants are much more complete and include, among other things, the amount of water treated, the amount of chemicals used and results of bacterial examinations of the raw and treated water.

Another activity of the Department in connection with the protection of public water supplies is the installation of emergency chlorination plants when and where deemed necessary, either for the purpose of averting water-borne epidemics or for the treatment of emergency water supplies in cases of shortage of regular supplies. Two chlorinators and also essential equipment for installation of emergency hypo-chlorite plants are maintained and ready for immediate use whenever required. The number of installations made vary greatly from year to year. During dry years as many as 10 installations have been made while during some years only one or two such installations have been necessary. When an emergency chlorinator is installed by the Department, it is maintained until the emergency is over, or until a permanent chlorinator has been secured by the water-works officials for the treatment of the water.

As indicated above, the supervision over the sanitary quality of public water supplies by the State Department of Health has been made with relatively little enforceable authority. It was not until this year that definite enforceable authority was granted through a law enacted by the Legislature this spring which provides as follows:

"When the State Commissioner of Health, after investigation of the condition of any public water supply used for drinking or other domestic purposes, whether maintained and operated by a municipality, water district or private corporation, company or individual, shall certify to the board, corporation, company, officer or person in charge of the maintenance and operation of such water supply that in his opinion such water supply is so polluted or subject to dangerous pollution as to constitute a menace to the public health and shall order reasonable emergency measures to be applied to such water supply for the protection of public health and such municipality, water district or private corporation, company or individual maintaining and operating such water supply shall fail to carry out such emergency order forthwith, any court of competent jurisdiction may, upon the application of the State Commissioner of Health, enforce prompt compliance with such emergency order."

We do not believe, however, that it will be necessary to resort to this law to carry out our recommendations in many cases, if we continue to receive the splendid and whole-hearted coöperation of the local water superintendents, water-works operators, water boards, water companies and local health authorities.

As a result of this coöperation and the close supervision by the Department of the public water supplies a marked improvement in the supplies of the State has been made. When this work was first undertaken by the Engineering Division in 1906, shortly after the State Board of Health was reorganized into the Department of Health, only about 700 000 persons were provided with filtered or treated water supplies, and the majority of the supplies were far from satisfactory. Today, approximately 8 000 000 people, equal to about 75 per cent. of the entire population of the State, are served with filtered or chlorinated water. There are, at present, 107 filter plants at nearly all of which the water is also chlorinated and 143 chlorination plants, exclusive of those installed in connection with filtration plants.

Needless to say, these improvements have been reflected in the typhoid fever death rate of the State, which has dropped from an average of 23.6 prior to 1906, when the Engineering Division was organized and active supervision of water supplies was commenced, to an average rate of 8.6 since 1906 and a rate of 2.6 for 1926. Massachusetts has a better record which, I believe, is due in a large measure to the fact that its State Board of Health was organized about ten years before the New York Board and that active supervision over water supplies was commenced in Massachusetts about 20 years earlier than in New York.

RELIABILITY FEATURES OF AN ELECTRICALLY-OPERATED PUMPING STATION.

BY R. C. DENNETT* AND GEORGE L. SWAN.*

[*Read September 14, 1927.*]

The modern trend in water-works practice, particularly as applying to the small town or village, is to depend upon electricity for the operation of pumps, air compressors, and other classes of machinery used in the delivery of water to the distribution system.

In the past the probability of interruption of electric service was in many cases so great as to prohibit the use of electricity, but in recent years the interconnecting of main generating stations by feeder lines and the greater dependability of generating equipment have resulted in providing a source of current which can be made almost perfect in its dependability. For water supply, however, there should be no interruption of service, as a shutdown at the time of a serious fire may result in the total destruction of a large part of the community served. In the steam-operated water-works station reliability can be obtained by providing reserve pumps, boilers and accessories. With the electrically-operated station this is seldom possible, as, even with duplicate circuits, there is still a possibility of an interruption occurring on both, with the result that there will be a total shutdown of service. Reserve generators can be provided and reserve motors for the various classes of service, but the existing uncertainty of the circuit to the operating unit is such that some provisions must be made to take care of this possible interruption of supply. Where circuits are overhead this possible interruption is materially increased by snow and wind storms, forest fires, or fires in buildings where the pole line passes through cities. Although the probability is decreased by the use of steel towers, there is still some hazard from the fact that the lines are subject to sleet and wind storms.

There are two ways of overcoming this hazard of interruption of service, namely, providing elevated storage for supply to the distribution lines of the water system, or installing sufficient reserve units which will not be susceptible to this interruption of supply of electric current.

Elevated storage provides a more dependable and desirable form of stand-by service. It is believed that any electrically-operated pumping station should have some elevated storage to fall back on, even though this storage be of such limited capacity as to be able to supply the demands of the water system only for a very short time, say thirty minutes to an hour. This small storage will suffice during the time necessary to shift over from one feeder line to another or for the power company to shift over from one

*National Board of Fire Underwriters.

generating station to another. It will also give fire supply during the time necessary to start up additional equipment, and it is therefore strongly recommended that regardless of size, every community that depends upon electric operation of its pumping station provide as much storage as the topography and other conditions will permit. For many cities this storage can be in reservoirs on the tops of hills, but in a considerable section of the country, particularly the central Mississippi valley section, no such storage can be provided at a sufficient elevation to give satisfactory service. For these places the water-works engineer must go to standpipes and elevated tanks. In recent years the use of elevated tanks holding 500 000 to 2 000 000 gal. of water have become feasible propositions, and many of them have been installed for both large and small water systems. These tanks also have a high economic value, as they permit a more uniform rate of pumping and maintain a more constant pressure throughout the system. It is, of course, essential that any elevated storage be connected to the distribution system by a pipe line of sufficient size to permit the heavy demands of fire and maximum hourly consumption to be met, without materially dropping the pressure in other portions of the city.

The second method of providing reliability has many different angles from which it can be approached. To provide sufficient reserve or stand-by equipment to prevent interruption of water supply from an interruption of electric service has usually, in the past, meant the maintaining of steam equipment. In many cases when the electric machinery was installed it superseded steam-operated pumps with their accompanying boilers and appurtenances, and it has been common practice to maintain this steam equipment for emergency use. Where there is no storage on the distribution system it is necessary to keep steam up on these boilers and have some of the steam pumps ready to operate at an instant's notice. This, of course, is expensive, and, in a number of cases, it has been noted that the officials of the city or town were willing to jeopardize reliability of supply by simply retaining the equipment as a reserve, but not maintaining it in condition for immediate operation. The boilers would be ready for firing but would not have steam maintained in them. A condition of this kind usually means that service cannot be resumed until after a lapse of two to three hours. Where boilers are fired with oil or gas, they can be put into service much faster, and the dangerous period is not so great, but with such a form of reserve equipment there is usually lack of proper maintenance. Pumps may be turned over by hand once every month or two but their general condition is never kept up to the point desired, and usually there is disinclination to spend any money for repairs and upkeep. After a few years such a plant is very apt to be practically useless as reserve equipment and to become a distinct hazard, as it gives the officials and citizens a false sense of security. In a number of installations, reserve steam pumps are not maintained, but, instead, the water department will keep ready for service a reserve generating unit and the necessary boilers to operate it. Such

generators probably furnish a more satisfactory reserve than the steam-driven pumps so often kept for emergency operation.

It is believed that the coming form of stand-by equipment for electrically-operated stations and also for steam-operated stations, where there is an excessively high peak demand for water at very infrequent intervals, is that operated by internal combustion engines as prime movers. These internal combustion engines can be of three general types: (1) those using illuminating or natural gas in which might be included gas engines supplied by local gas generators; (2) the Diesel or semi-Diesel engine in which crude or semi-crude oil is burned under high compression in the cylinders; (3) the gasoline type of engine.

The gas engine has not come into very extensive use, partly because the gas companies have not always wanted to cope with a heavy demand which might be made upon the gas system, possibly at the time of maximum domestic demand for city gas. The Diesel or semi-Diesel machines have an advantage of low cost of operation, and the installation of such prime movers will become more common as the years go on. The first installations were lacking in dependability and always introduced the factor of not being able to obtain a competent operating force. The Diesel engine class is satisfactory as a reserve or stand-by unit but has a high first cost, and therefore the extensive installation of such machines for very infrequent operation is not looked upon very favorably by water-works officials. Usually these machines are installed for reserve, and an insufficient number of the machines is put in, thus only partially correcting the condition brought about by an interruption of electric service. A very satisfactory combination of electric and Diesel engines is one where approximately half of the equipment is electric and the other half Diesel. It thus becomes necessary to operate the Diesel engines during peak demands or for normal fire service, which is not at all objectionable as the economy of these machines is such that it normally makes very little difference whether pumping is by electricity or by the Diesel engine. The Diesel engine has one advantage over other types of internal combustion engines in that it can be built in large sizes; therefore its field is largely that of the cities and towns of considerable size.

The gasoline-driven pumping unit is probably the most economical and dependable of all forms of reserve equipment. The mechanical details of gasoline engines and the various appurtenances that go toward the successful operating of these machines have been so far perfected by the automobile industry that such units must be given a high rating for reliability. The troubles, formerly experienced from poor starting devices, indifferent ignition systems, improper carburetors and poor lubrication, have been largely overcome. In addition, trained operators and repairmen are available in even the smallest village. There is also greater uniformity of fuel supply. The initial cost of the gasoline engine is very low, and the operating efficiency is being increased each year with improvements in the design

of the machine itself. Such units have a further advantage in that the floor space occupied is very small, and the appliances can be installed in existing buildings without a material rearrangement of other parts of the plant. The principal objection raised to the gasoline automobile type of engine is the relatively small capacity of the pumping unit which can be operated. This, however, is really an advantage from the standpoint of dependability of service as there is less chance of interruption of supply to a water system where there are six units of 1 m.g.d. capacity each than there would be with two units of 3 m.g.d. capacity. It is probable also that six units could be installed at a smaller total cost, as standardized engines, manufactured under conditions of mass production, can be purchased and as the size of suction and discharge pipes will be smaller and the foundations lighter. A few years ago it was strongly recommended to the officials of Cincinnati that they install a pumping station to supply their high pressure fire system and that they use in this station a large number of gasoline-driven centrifugal pumps. It was estimated that the floor space occupied by such pumps and the crew necessary for operation would not be larger than required for larger Diesel engines or steam equipment.

The objection has been raised by some that gasoline engines introduce a distinct fire hazard in the pumping station due to the known hazard of the gasoline fuel. It is felt that sufficient steps have been taken towards providing safeguards for the storage and handling of gasoline to make this objection of little moment. The National Board of Fire Underwriters has issued regulations covering the installation of gasoline-driven fire pumps for industrial plants, and by following these regulations a municipal pumping station using gasoline engines would not be considered hazardous.

We have discussed above the various features dealing with methods of providing reserve service to offset the probability of interruption of electrical supply. While it is felt that the conditions stated must be complied with in one way or another wherever electric operation is depended upon, it is also believed that every possible safeguard should be thrown around the electrical supply itself. The ideal condition of such supply is one where current is brought in through two underground lines, each extending along a separate route to the pumping station from an independent generating plant. This ideal arrangement can seldom be made, and the nearest approach to it is usually two underground supply circuits from a common network of main feeders. In either case, it is desirable that two circuits be run to the pumping station, and these preferably should be independent and not be used to supply other consumers. Each circuit, of course, should be of sufficient capacity to operate enough equipment to maintain the fire demand at time of maximum consumption. This does not mean the maximum peak rate of consumption but the maximum rate of water for any twenty-four-hour period. Providing in duplicate of two separate generating lines does not cover all the features of reliability which should be maintained in a water-works system. There are other points, such as the type

and arrangement of transformers, the number and kind of switches, the arrangement of bus bars and the character of switchboards. Consideration must be given to these features, not only at the pumping station, but also at the generating station, as in every instance the electrical equipment from its source of generation to the pumping station must be of such character as to permit continuous service, if it is possible to accomplish this task.

The increase in the use of electric drive for pumping apparatus has been coincidental with the improvement in the design of electric motors, which now have a reliability equalling or exceeding that of steam engines, although not requiring the same degree of skilled attendance. This latter characteristic, however, may readily become a feature of unreliability, as the adaptability of electric drive to automatic or remote control presents a severe temptation on the part of officials to omit all attendance in isolated plants except a periodic inspection of oil bearings.

There is little difference, as regards reliability, between the alternating and direct current types of motors, with a slight advantage in favor of the former, because of the absence of commutators and brushes. Due to the difficulties in economically transmitting direct current over long distances, direct current motors are infrequently used, except where the current is generated within, or a short distance from, the pumping station; the feature of unreliability of long transmission lines is therefore seldom present with this type of motor. Induction type, alternating current motors are used in the majority of cases to drive pumps and are dependable and simple to operate. While the squirrel cage type of induction motor obviates the use of slip rings, its excessive starting current makes it less desirable in the larger sizes than the wound rotor type.

Because of their beneficial effects upon power factor and the consequent favorable contracts obtainable from public service companies, synchronous motors are coming into favor for driving pumps. This type of motor has undergone considerable development within the past few years, and a self-excited synchronous motor, with reliability characteristics comparable to those of the induction motor, is now available. While not adaptable for service calling for variable speeds, synchronous motors present a satisfactory means of driving pumping units, which normally operate at a fixed speed.

In all cases, however, where such motors driving pumps require a separate auxiliary machine to bring them up to synchronous speed, or to furnish exciting current, such auxiliary machines should preferably be direct-connected or provided in sufficient number and of sufficient capacity, with two out of service, to start or furnish exciting current for all pump motors necessary for fire flow and maximum domestic consumption. The same assurance of continuity of exciting current should be provided for the alternators at the generating station.

Sufficient time lag in the operation of starting devices or automatic

circuit breakers is sometimes necessary with synchronous motors to prevent the motors dropping out on momentary dips in line voltage; this lag must not be so great, however, as to prevent the circuit breaker from operating to remove the motor from the line on loss of line current for longer periods, unless automatic devices are provided for re-starting motors from a standstill.

The use of relatively high tension supply lines requires transformers to reduce the voltage to within working limits, and these introduce a reliability hazard due to the presence of oil used for cooling. Some of the larger sizes of transformers contain up to 5 000 gal. of oil and present a serious potential fire hazard, if located in or near the pumping station, although if properly installed in fireproof vaults with adequate provisions for drainage of oil, or located out of doors at a sufficient distance from the station, the actual hazard may not be great. Within the last two years, a fire in a transformer, temporarily located immediately under the windows of the generating station in Savannah, Ga., resulted in the wetting of the switchboard and apparatus within the station by fire department streams, shutting down electrically-driven pumps and leaving the city without water for several hours until the equipment could be dried out.

Three-phase alternating current is generally considered to afford greater reliability of continuity of service than single- or 2-phase. With transformers connected delta-delta, the failure of one transformer of a bank would still permit the operation of a 3-phase motor at approximately two-thirds capacity. Although a 2-phase motor could be operated as a single-phase motor in case of failure of one phase, difficulties would probably be experienced due to unbalancing of the system and the motor could not be started without special phase-splitting devices which would be needed only for such an emergency and consequently would seldom be at hand.

Oil switches are generally used to control the larger sizes of motor and to connect feeder lines to station busses. These frequently contain a considerable quantity of oil, and, because of the fact that they are breaking heavy currents, draw more or less of an arc on operation, breaking down the chemical structure of the oil and generating gases that sometimes attain explosive proportions. Oil switch explosions are by no means rare occurrences. For this reason such switches should be isolated from switchboards and other electrical machinery and located in fireproof enclosures. Disconnect switches, on either side of oil circuit breakers, are necessary to permit repair of the breakers, wherever there may be a possibility of a feedback of current.

Where continuity of service is of paramount importance, the switchboard must provide unusual flexibility of connection from the feeders to the motors. With two separate feeder lines, this may be accomplished by a loop system of busses, with proper sectionalizing switches, or by a single set of bus bars with double-throw switches. Whichever system is used, interlocking relays must be used on the feeder circuit breakers to prevent

the possibility of both feeders being connected to the busses at the same time, unless the lines are fed from the same generator or transformer.

Although, as previously stated, the most serious element of unreliability in the use of electric drive has been the transmission line, it is quite possible to build lines sufficiently strong to practically eliminate failures due to ice and sleet and to so locate them as to avoid exposures from burning buildings or other possible causes of mechanical failure. Greater difficulty is experienced in protecting long lines against direct lightning strokes, or high potential surges induced by lightning, switching operations, or abnormal line conditions. It is standard practice to guard against such disastrous surges by the use of lightning arresters, choke coils and reactors at each end of the line.

With the development of so-called super-power projects and the very general interconnection of generating plants now prevailing, it is usually not difficult to secure separate services from two or more generating stations or from a system supplied by interconnection of several stations. Such interconnection of systems has shown a very favorable service record for continuity of service in the districts inundated by the recent Mississippi floods.

Discussion.

Allen Hazen.* Electric pumps have been installed in large numbers in the last few years. The business is satisfactory; it is increasing, and very few troubles are experienced.

The authors are right in stating that where electricity is substituted for steam in direct service, an elevated tank is desirable and in fact almost necessary. Fortunately elevated tanks are much more practicable than they were some years ago, and the use of a tank will steady the operation of the motors and be most beneficial.

Synchronous motors have been most commonly used on pumps, and the makers of pumps have usually favored these motors and have usually represented that such motors give the highest efficiency.

This matter has been the subject of special study in our office and it has been found that in many cases slip ring motors are more economical in actual service. Where the load is constant, the synchronous motor will always be more economical; but in many water-works operations with widely varying loads the slip ring motor has great advantages and frequently turns out to be best.

In the early days of electric pumping, steam stand-bys were thought to be necessary, but the electrical equipment has become so reliable that much less thought is now given to them.

A. O. Doane.† I think this paper is very instructive and gives a very fair account of the present state of the art.

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The authors have discussed steam operation, or, rather, holding steam equipment as a reserve. Steam equipment is a very unsatisfactory reserve for any other form of power because of the difficulty which the authors touched upon, but which the writer does not think was stressed enough, of keeping the steam equipment in readiness to run.

One of two things must be done: one is to keep the equipment in constant readiness to run at any time. This necessitates keeping a force of firemen and keeping up steam, or at least maintaining banked fires; when this is done, the expense is entirely prohibitory and not much of anything is gained by the use of electric current. The other alternative is to keep enough equipment in readiness to run, but without fires or firemen. In this case the boilers should be empty, because, as any steam engineer knows, if the boilers are kept full of water, they will suffer serious injury in a comparatively short time. If the boilers are empty and the equipment is laid up for a long time, it takes quite a while to get up steam. The equipment cannot be working in less than ten or twelve hours, if fire tube boilers are in use. Also, it is disastrous to boilers to heat them too quickly.

From this, it seems that steam reserve is unsatisfactory and gives, as the authors say, a false feeling of security.

Another form of reserve is the Diesel engine or the gasoline engine. The Diesel engine is best for large reserves, and the gasoline engine for smaller equipment, or multiple units, as the authors have stated.

Recently the writer looked up this matter in Chicago, and found that, in the Sanitary District, large Diesel engines are used as a reserve for electric equipment. One of the engineers made the statement that these Diesel engines operate at frequent intervals which is, of course, good practice, and that, in some cases, the Diesel engines were found to operate at a lower cost than the electrically-operated machinery. The question arose as to the use of Diesel engines only. The low cost of electricity, however, less than one cent per k.w.h. in large quantities, decided against such use.

Electricity is very good for small or medium-sized plants, and, under proper safeguard, it can be used for larger plants, and undoubtedly will be, but it should be surrounded with every safeguard. The writer has not yet come to the point where he thinks that a station should be operated entirely automatically, where fire protection is at stake, or where large pumping service is required.

ARTHUR L. SHAW.* "There is one feature in which municipal electric pumping usually differs from the ordinary industrial application. Nearly all industrial plants use relatively low voltages, 220, or possibly 440 or 550 volts. Municipal plants, on the other hand, tend more and more to the use of motors designed for high voltages, thereby eliminating transformers and frequently obtaining more favorable rates from the power companies. For example, we have found it advantageous to use 4 000 volts at the Kennebec Water District pumping station, Waterville, Maine; 6 600 volts

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in both water and sewage pumping stations at Dayton, Ohio; 4 000 volts in a sewage pumping station at Allentown, Pa., and 2 200 volts at the pumping stations of the Gloucester Water Works.

The use of high voltages makes the starting, control, and protective equipment somewhat complicated and expensive. It also requires the employment of somewhat more intelligent operators than are required for low voltage installations. All these facts must be taken into consideration in determining whether it is advantageous to adopt high voltage in any particular project.

CHARLESTON'S TWO MILLION GALLON ELEVATED TANK.

BY J. E. GIBSON.*

[*Read September 15, 1927.*]

There is little new or very novel in the Charleston Elevated Tank. However, an old adage runs, "Pretty is as Pretty does," and by this measure our tank is some "Beauty."

The peninsula upon which the city is located is formed by the Cooper and Ashley rivers and has a width, at its southern end, of about one mile; and at the neck, five miles north, of one-half mile. The average elevation of the city does not exceed 10 ft. above mean sea level, and to obtain elevations of 100 to 150 ft., it is necessary to go inland from 30 to 50 miles.

Goose Creek, a tidal tributary of the Cooper River, is the source of the city's water supply. The impounding or storage basin is formed by a dam which performs the double function of retaining the fresh-water inflow and of restraining the salt-water tidal flow from the Cooper River.

The pumping station and filter plant are located near the storage dam site, 13 miles from the City Hall and 11 miles north of the city limits. Situated between the pumping station and the city limits are a number of large industries requiring in the aggregate 1¼ m.g.d. and having a peak demand of 3 m.g.d. The city proper has an average consumption of about 4 m.g.d. and a peak demand of 8 m.g.d., so that, when the peak demands of the city and industries occur simultaneously, it means a total demand on the pumping station of 11 m.g.d.

Previous to the installation of the tank, our maximum load during the morning hours averaged 10.5 m.g.d., requiring a pumping pressure of 125 lbs. to maintain an adequate pressure in the city. This load fell off during the afternoon and by 7 P.M. the demand was reduced to about 6 m.g.d., with a pressure of about 100 lbs.; and from midnight until 6 A.M., the demand fell as low as 3 m.g.d., with a pressure of 60 lbs.

From a series of careful observations covering the operations of the plant, quantities and pressures being observed, with the corresponding information obtained in the George Street office down-town, charts were prepared to govern the operation of the plant as to quantities of water to be pumped and pressures to be maintained. With careful operation on the part of the engineering force at the plant, fairly satisfactory pressures could be maintained down-town. Peak demands, however, occurring suddenly, especially so by any of the manufacturing interests located between the plant and the city, would occasion severe drops in pressure and cause the pumping machinery to speed up rapidly to meet this demand; then, the

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demand passing, the pressure would often mount to dangerous heights, placing a serious hazard upon both pumping machinery and distribution system. To relieve this hazard, coöperation was established with the industrial concerns between the pumping station and city limits, and most of these industries installed supply tanks upon which they could draw to meet their peak demands. It was not always possible for them to so regulate their supply as to avoid entirely sudden demands on the mains; then again, the shipping interests down-town placed sudden demands on our lines. The Clyde Line steamers coming in with light cargo for Charleston would often discharge in a few hours during which time they wanted to fill up their water tanks, so as to have sufficient water to carry them to Jacksonville, Fla., and return; they preferred the Charleston supply over the Jacksonville supply for boiler purposes.

We installed Venturi meters at the pumping plant to measure the entire supply leaving the pumping station, and at the city limits we have a second set of meters that measures the water entering the city proper.

Realizing that large storage located somewhere down-town near the center of distribution would permit us to run our pumps at a fairly uniform rate and would maintain a uniform pressure on the system, we began to study the problem to determine the amount of storage and elevation required. By the use of a mass diagram covering a week of high consumption, as recorded by the meters, we found that a storage of 1.5 million gal. at an elevation of 120 ft., located near the center of distribution, would maintain a uniform pressure in the city and permit a uniform rate and pressure to be maintained at the pumping station.

Two tanks 56 ft. in diameter, 120 ft. high, or one tank 80 ft. in diameter and 120 ft. high, would give us the desired results. Upon taking the matter up with the tank and standpipe builders throughout the country we found that an 80-ft. diameter tank was feasible and that the cost was less than for the two tanks. Early in 1925 a contract was let to the Chicago Bridge & Iron Works for an elevated steel tank, with ellipsoidal bottom, having a total height of steel work of 115 ft. The tank proper had 35 ft. of cylindrical shell, with an ellipsoidal bottom extending 26 ft. below the vertical shell and connected with a 14-ft. riser pipe extending to the top of the foundation which is 5 ft. above the average elevation of the ground. The tank is supported by 24 vertical Bethlehem H-section columns resting on concrete piers, pyramidal in form, the tops of which are 5 ft. above average ground level and which extend 5 ft. down into the ground. The total height of the tank above the street level is 130 ft., the lot being terraced up from the street.

The question as to the safe bearing value of the soil was one of the most interesting points, and test holes were bored on the site to determine the nature of the underlying soil. The information obtained from these holes was as follows: 1 ft. of top soil, 18 ft. of dry yellow sand, 9 ft. of tough dry clay, 4 ft. of light yellow sand containing small shells and water, 14 ft.

of dark gray sand and water, 10 ft. of clay, mud and shells lying directly on top of marl 56 ft. below the surface. The thickness of the marl in this section varies from 300–600 ft. Tests for bearing values were made by means of a weighted platform surmounted on a square timber post having an area of approximately 0.5 sq. ft. Tests were made at three different locations, none of which, however, was within the area occupied by the foundation of the tank. Results of the tests were as follows:

	Settlement in inches.		
Loading in lbs. per sq. ft.	Location: No. 1.	No. 2.	No. 3.
4 000	1.125	1.00	0.25
6 000	1.800	1.125	0.60
10 000	2.64	1.920	1.56
12 000	....	....	1.92
14 000	....	....	2.08
16 000	....	....	2.52
Final after Twelve Days:			
16 000	....	....	2.64

Minimum period between loadings, 24 hours.
No rain occurred to soften the soil during period of test.
Locations 2 and 3 are more representative of the soil conditions upon which the tank stands.

Thus, the settlement varied from ¼ in. up to 2.6 in., depending upon the load and the location. The tests indicated that there would be some settlement of the concrete foundation, but the question was to properly distribute the load on this soil so as not to exceed 2¼ tons per sq. ft., including live and dead loads and foundations. The pyramidal form of construction for column piers was selected, and, in order to keep the yardage and the stresses in the concrete both within reasonable limits, deformed steel bars were used; here I wish to say that I think it would be advisable for the tank builders to give the matter of foundations greater consideration since this feature of the design has considerable influence on the final cost of the entire structure.

After the tank was completed we filled it and took observations on each column pier, noting the settlement as the tank filled. The maximum settlement of any one pier was 1.656 in.; the minimum, 1.333 in.; average, 1.512 in. We had anticipated minimum settlement of an inch and a maximum settlement of 1.5 in. We then emptied the tank for the placing of bitumastic enamel on the inside; this was completed the latter part of May, 1926. A second series of levels taken after the tank was emptied indicated that the foundations rose on the average of .375 in. A third series of levels, taken when the tank was filled for the second time and just prior to its being placed in service, showed the foundations to have again settled back to the same elevation that they reached under full load the first time. We understand that this practically accords with another case where, after taking the load off after initial filling, the foundation rose, and on the second filling the settlement exceeded the first slightly, after which no further settlement occurred.

Quite a unique feature of this tank is the overflow trough; and it must be borne in mind that Charleston has a very mild climate and only occasionally do we have ice. (I have lived in Charleston for ten years, during which time ice has formed on our storage reservoir only once, and then of a thickness just sufficient to bear one's weight.) During the usual winter we get only a very thin skim of ice and then only in the more exposed places. The tank is built in a residential section that is not yet entirely built up. If it were not for the overflow trough, future residences might be damaged by water being washed over the edge of the tank by high winds. This overflow trough is constructed on the outside edge of the tank, is 18 in. deep and 18 in. wide, and its outer edge projects to a minimum height of 6 in. above the inner edge of the tank. This trough also serves as a stiffening girder around the top to maintain the tank in its true shape in the same manner as a balcony girder. Leading from this overflow trough down one side, as indicated in the accompanying figure, is a 12-in. conductor pipe which conveys the water to the sewer or drain. By this means we hope to eliminate complaints from property holders, caused by any overflow that may occur due to too high a rate of pumping or due to wave action. This type of construction, of course, would be impossible in a locality where ice forms every winter and for a considerable period of time.

The maximum thickness of any plate in the tank is $\frac{3}{4}$ in. in the ellipsoidal bottom. All seams in the bottom and the first ring to which the supporting columns are attached are of quadruple-riveted, double-butt, strap-type joint. The seams above the first ring are quadruple, triple, double-, or single-riveted lap joints, as required. All horizontal girth seams are single-riveted lap joints, with the exception of the junction between the first ring and the ellipsoidal bottom and the girth seams in the 14-in. riser pipe which are double-riveted lap joints. The double-riveted, lap-jointed girth seams in the 14-in. riser pipe were made necessary, due to the fact that we considered the possibility of one-sixth of the total load being carried on this riser pipe, acting as a column. In order to secure sufficient bearing and shearing value in these joints it was necessary to use double-riveted lap joints.

Standard structural shapes were used throughout the tower construction, and Bethlehem H-columns were used for the tower columns. The advantage of this type of construction is the ease of cleaning and painting, making for better maintenance. The design of the tank was based upon the following unit stresses, and in all cases the actual unit stresses of the designed structure were well within the limits given:

Working stresses in plates and members, bottom of tank, and first ring where columns of tower join shell of tank	13 000 lbs. per sq. in.
Vertical plate above bottom ring	18 000 lbs. per sq. in.
Steel and structural tower	18 000 lbs. per sq. in.
Bearing value on soil	2½ tons per sq. ft.

Wind pressure corresponding to a hurricane velocity of 100 miles per hour.

The total weight of the tank when full, including foundations, is 22 120 000 lbs.; the weight of the steel work, 1 350 000 lbs.; and the weight of the water 17 170 000 lbs. Minimum thickness of any plate in tank shell and riser pipe is $\frac{3}{8}$ in. and in the overflow trough $\frac{1}{4}$ in.

FIG. 1.

At first the tank was not covered, but later it was decided to cover it, and we have since provided a dome-shaped roof, supported on steel trusses riveted to the shell of the tank. (See figure.) The roof envelope proper is $\frac{3}{16}$-in. copper-bearing steel, electrically welded. The tank is located just off Meeting Street in the residential section of the city, which at present is poorly developed and of very inferior character. It is our intention to beautify the lot later by the planting of shrubs and trees that will camouflage the tower structure.

The tank has been in service since June, 1926. It has proved exceptionally satisfactory in that we have been able to maintain a uniform pumping rate at the pumping station with uniform pressure throughout the twenty-four hours, and since its installation it has been called upon a

number of times to supply service that, under the old conditions, would have been much of a handicap. Such service was called for twice by heavy demand for fire purposes, when there was probably a demand of 6–7 m.g.d. over and above the normal consumption. With the tank in service, the lowering of the pressure on the city mains amounted only to a few pounds, not exceeding ten at the maximum, whereas with the Holly or direct system it would have required a minimum of at least 10–15 minutes to have met this demand and the hazards incident thereto. We have been able to make repairs to our valves in the 24-in. pumping main during ordinary periods of the day without interrupting the service to the city. Heretofore we have had to inconvenience the consumers and to do this kind of work at night and on Sundays. We have had no less than two breaks in our distribution system that would have seriously affected the pressure and the demand on the pumping station, had not our tank been in use. Not longer ago than Sunday morning, September 4, 1927, our 24-in. main broke, a piece of pipe, probably 15 in. in diameter, blowing out the side of the main and thereby reducing the pressure at our pumping station to 15 lbs. With the old Holly system this would have meant that the city would have been entirely out of water until the break was located and the broken sections valved off.

Since the completion of the tank we have duplicated our trunk main from the plant to the city, and we now have two 24-in. mains for the 12 miles between the tank and the pumping station. This has further reduced our pumping head requirements and has reduced the hazard on trunk mains, the pumping station, and the distribution system.

Our conclusion, after one and one-half years of experience and operation of the tank, is that elevated tanks offer a most useful service in any water distribution system, and, if properly designed and located, will relieve the distribution system and mains of excessive pressure and supplement them in every way. In old systems, the necessity of replacing small mains by larger mains can be materially delayed. The life of small mains can be materially increased by the strategic location of elevated tanks, and the heavy costs of replacement with larger mains under improved pavement conditions can be materially deferred. By proper treatment, parking, painting, planting of shrubs and trees, these tanks can be camouflaged and add sightliness and beauty to a community. We believe that, as the many advantages of elevated tanks and standpipes are better understood, they will come more and more into use in our water-supply systems.

Discussion.

A Member. I would like to ask what the approximate cost of the elevated bank was.

Mr. Gibson. The steel work in the tank proper, including the roof, ran about $80 000. The foundations cost close to $18 000. The total expenditure of the city amounted to about $110 000. The land was a minor item. We had to lay a line of pipe from our existing system over to the tank to supply the tank and to act as a feeder to supply back to the system. We pump at a uniform rate of about 5½ m.g.d. and let the tank float directly on the distribution system; we do not use it for storage. We have found, however, that, due to the consumption of water by the manufacturers between the city and the water works, it is possible to pump at a higher rate during the day than at night. The total friction loss in the mains during the day is less than at night, due to the relatively shorter length of main to the center of distribution. We maintain a uniform pressure at the plant, notwithstanding this higher rate during the 12 hours of daylight. That is a detail we worked out afterwards, as we had not considered this condition at all.

Alexander Orr.* I am very much interested in this paper because it parallels a recent experience in Gloversville. Here a gravity system feeds the city through an 18-in. pipe line, collecting the water at the foothills of the Adirondacks. In 1908 I persuaded my commissioners to install a Venturi meter on this line. After it was in operation we found the following: water was being delivered through the pipe line to the city at a peak rate of 5½ m.g.d. and at a minimum rate of 0.5 m.g d. The Bristol recording gage in the office showed a daily fluctuation between maximum and minimum pressure of 17½ lbs. The question of equalizing these conditions was taken up and a survey made, and the decision was reached to build a standpipe. We were very fortunately located with respect to elevations. Our supply enters the city from the northeast. At the southeast corner of the city is an elevation suitable for standpipe construction, and a study of the northeast corner showed a hill on which we could build a concrete reservoir. An alternate to this plan of development was the addition to the 18-in. pipe line of a 24- or 30-in. line for a distance of about 6½ miles. Our consumption situation is similar to that at Charleston. The principal consumption of water is by large leather tanneries which want a lot of water in a few minutes and which consequently want big connections. As the result of the survey we decided to build first a steel standpipe in the southeast section of the city. A standpipe was built, 60 ft. in diameter and 55 ft. in height. When it was completed we found that our pressure charts in the office showed a reduction to a maximum difference of 12½ lbs. The maximum rate of flow registered by the Venturi meter was 3½ m.g.d. We next built a concrete reservoir in the

*Superintendent of Water Works, Gloversville, N. Y.

northeast section of the city. It has a capacity of 5 million gal. and is connected to the gridiron system of the city. Now we are holding our Venturi meter charts at almost a perfect circle, and our pressure curve in the office shows a maximum fluctuation of 2½ lbs. This development has cost less than one-half of what it would have cost to put in the 30-in. main.

THEODORE L. BRISTOL.* I would like to ask why the riser in the standpipe is so large. Is it for the purpose of carrying the weight? I do not understand how connection is made with the riser from the main; how large a pipe is used, and where it comes in.

MR. GIBSON. As regards the size of riser pipe, we called for bids, and, since we were dealing with a large tank, we wanted to give the builders every latitude we could; we therefore did not restrict bidders in what they were to bid on. All told we received about 80 tenders on eighty different combinations. The smallest-sized riser pipe was 4 ft. and the largest was 14 ft.; the average was about 8 ft.

There were a great many other details of design that differed. Some designs showed 12 legs, some 16, some 20, and the tank accepted had 24 legs. We thought a 10-ft. riser pipe was satisfactory, but we did not object to the 14-ft. pipe. When we studied the prices the 14-ft. proposition seemed to be the cheaper and more desirable one, and it met all of our requirements in all other regards.

The pipe supplying the tank is a 24-in. pipe. Connection is made with the tank through a one-eighth bend which reduces from 24 to 16 in. and enters the tank through a flange connection. The two joints on the 16-in. pipe coming out of the tank and running down to the surface of the ground are bell-and-spigot joints. The velocity, of course, is high, but the maximum draft through the connection probably never exceeds 1.0 m.g.d.; the length, furthermore, is less than 20 ft., so that the friction loss is very small.

*President, Ansonia Water Co., Ansonia, Conn.

PROCEEDINGS.

FORTY-SIXTH ANNUAL CONVENTION.

BOSTON, MASS.

September 13–16, 1927.

The following is a synopsis of such parts of the proceedings at the Boston convention as appears to be of value for the record.

The Forty-sixth Annual Convention of the New England Water Works Association was held at the Hotel Statler, Boston, Massachusetts, September 13–16, 1927.

The exhibits of the Associates were located in the Georgian Room on the Mezzanine Floor of the Hotel. The technical sessions were held in rooms adjoining the Georgian Room.

TUESDAY, SEPTEMBER 13.

Morning Session.

Vice-President Arthur D. Weston, Chairman of Committee in Charge of Convention Activities, in the chair.

MR. WESTON. It gives me great pleasure at this time to announce that the Convention Committee has carried out your instructions and that the results of the Committee's efforts are incorporated in the program which is before you.

The Committee felt that it was only fitting for an organization like ours, established in the city of Boston some forty-six years ago, to have the benefit of a few words of advice from the Governor's office at the State House, and also from the offices of His Honor the Mayor of the City of Boston and His Honor the Mayor of the City of Cambridge.

It gives me great pleasure to introduce to you, Mr. Davis B. Keniston, representing His Excellency, Honorable Alvan T. Fuller, Governor of the Commonwealth. (*Applause.*)

(REMARKS BY DAVIS B. KENISTON, CHAIRMAN OF THE METROPOLITAN DISTRICT COMMISSION.)

MR. KENISTON. Mr. President, Mr. Chairman, Members of the New England Water Works Association: I know that it is a matter of regret on the part of His Excellency the Governor, and I am sure it is on your part, that he could not be here personally to express his pleasure at meeting you. He has had a rather trying summer of work and has felt that he should, for a time at least, be relieved of as many of his public duties as possible. In

his absence he desired me to express to you his pleasure that you are meeting here in Massachusetts and in Boston, and to extend to you the greetings and welcome of the Commonwealth.

I think that few people who are users of the public water supply realize the problems and difficulties that the supplying of pure water involves. The source is usually obtained some distance from the point of use, is developed only as a result of carefully conceived and executed plans and can only be maintained as the result of constant care and attention. These are the problems and difficulties that you meet; that your work is well performed is best proved by the fact that the ordinary citizen never has to give it a thought and always has an adequate supply of good water at all times.

A story is told of a resident of the Swift River Valley, into which the Metropolitan District is going for its new supply. This man came to Boston and, while here, desired to telephone to his home. He went to the public pay station and gave his number in the Enfield Exchange, which is one of the towns in the valley. The operator asked him where Enfield was; he replied, "Why, that is one of the towns that is going to be taken for your water supply." The operator said, "What water supply?" He was very much aggrieved to find that the flooding of the towns in the Swift River Valley was not a topic for as interesting conversation here in Boston as it was in his own community.

The State, however, well realizes the difficulties and problems that you face. Through its Public Health Department it exercises supervision from a health standpoint over all public water supplies, and the Metropolitan District Commission is preparing to supply water to the cities and towns of the Metropolitan District comprising a population of substantially one-third of the entire State.

Among your past and present membership and officers I found many of those who have been connected, directly or indirectly, in one manner or another, with the Department of Public Health or with the Metropolitan System or its predecessor, the Boston Water Works. Last year when the State started on its work of developing its new supply for the Metropolitan District, it looked to your membership to supply it with a chief engineer. I am not quite sure whether the State chose your president as its engineer, or whether your Association selected the State's engineer as its president; in either event I think that both may feel gratified at their choice, and I think that your president has not been dissatisfied with his duties.

I notice that you have a very full program during your four days of gatherings and that your time seems to be well occupied, but I would like to express the desire of the State to extend every courtesy possible to any of your members who may be interested in any feature of the Metropolitan Supply, either of existing works or of the new extensions. Let me also hope that your four days of gatherings may be filled with all possible benefit and pleasure. (*Applause.*)

MR. WESTON. The Honorable Malcolm E. Nichols is unable to be with us this morning. I know that he desired very much to be here, but all those who follow the papers closely will have noticed that he has had laryngitis for a period of several weeks. The Mayor has very kindly donated to the Association a cup which is to be presented to our member who comes to the Convention from the greatest distance. That cup is now in the farther corner of the room. I would like you all to see it before you go out.

Mayor Nichols has sent a man to represent him this morning whom it seems unnecessary to introduce to you. He is an old member of the New England Water Works Association, and I think you are all very well acquainted with him; for those who have not met him I want to introduce Mr. Louis K. Rourke. (*Applause.*)

(REMARKS BY MR. LOUIS K. ROURKE, BUILDING COMMISSIONER OF THE CITY OF BOSTON.)

MR. ROURKE. Mr. Chairman, Mr. President and Gentlemen: His Honor, Mayor Nichols, sent me here this morning to express his regrets that he is unable to be here in person to greet you. I am sorry for this, because I think he could give you a very interesting talk on his activities during the past year in connection with the legislation which was passed for the extension of our Metropolitan Water System.

As you know, Boston is endowed, you might say blessed, with a good and abundant water supply, the possession of which is due in no small measure to the work of members of this Association. The extension of this system is guaranteed by the legislation that was passed last year, and I am sure that the prompt and efficient completion of the proposed extension is assured in view of the fact that it is in the hands of Mr. Keniston and of Mr. Winsor, your very capable president.

I have not prepared any address of welcome; you do not need any. This is your home. As far as I know, you have not been very far away from home and always have been on the job. For some years I was a member of the Association, and my recollections of the contacts then established are very pleasant indeed. The meetings are businesslike, and I never went away from any of them that I did not carry away some practical information that was useful to me in my work.

The only thing I can say is that I am delighted to renew some of those contacts and that I convey to you the wishes of the Mayor that you have your usual profitable and pleasant convention. I thank you. (*Applause.*)

MR. WESTON. The City of Cambridge is often considered the sister city of the City of Boston, and the chief executive of that city is a man who, the greater part of his life, has been wrapped up in water-works problems. I want you to meet the Honorable Mayor Quinn of Cambridge. (*Applause.*)

(Remarks by Hon. Edward W. Quinn, Mayor of Cambridge.)

Mayor Quinn. Mr. Chairman, members and friends of the New England Water Works Association: I see by the program that I was billed for a speech, but I, like Louis Rourke, have prepared nothing at all to give you, excepting to say to you that in Cambridge we have prepared to meet the delegates on Thursday. The purpose of that invitation is to give you an opportunity of viewing the new plant that was built some few years ago, the rapid sand filtration plant.

You know it is always a pleasure for me to hold my membership in the New England Water Works Association, and also in the American Water Works Association. I have had a fine opportunity of coming in contact with those who are experts in their particular line and of learning something which was beneficial to the city. I had the good fortune at one time of being the superintendent of water works of Cambridge. I was formerly superintendent of streets, and then I saw a much easier job in the superintendency of water works. (*Laughter.*) You see most of the water-works troubles are underground. But today, with the great problem of traffic and road conditions, I said to myself that if I could work my way into the water-works department I would probably have an easier time. Then I had ambitions to go higher. I think I would probably have been better off if I had remained superintendent of water works, because I had a home and everything free out there. (*Laughter.*) Now at least I have got to pay rent. But it was always a pleasure to meet the different delegates that I see gathered here and to learn the things that are in use and that have been of great benefit to me as Mayor of Cambridge.

I had a very peculiar experience as far as the water-works superintendency was concerned, in Cambridge. When I was elected mayor I appointed the ex-mayor as superintendent of water works; and if he and I play the game as we think we ought to then, when I get through as mayor, I want him to be mayor and I want to be superintendent of the water works again. (*Laughter.*)

I am glad to come here, and I do hope, like Louis Rourke, that your stay here is going to be a pleasant one. I do want you all, if you can, to accept the invitation extended by Cambridge. We think we have the last word in filtration. There is always a difference of opinion as to the merits of rapid sand and slow sand filters, but we think that we have the best, and we are going to give you the opportunity to see it. We have a very fine plant, which was designed and constructed under the direction of Col. George A. Johnson, and we tried to make it as comparable with Harvard University as we possibly could. In building it we spent a lot of money on the structure itself, and we think we have a fine plant.

You know it is a great thing, particularly now, to have this pure water, because if we had had pure water years ago the people would not have recognized it; but at this particular time I suppose that White Rock might

be a great thing, but it is not in Cambridge. You know they do not sell any White Rock in Cambridge. It is mostly all Cambridge water that we drink and bathe in. That is because it is so pure and because it has that sparkling effervescence — whatever that is. (*Laughter.*)

But I am not going to take your time; I realize that this is a very important convention. I am glad to have your Association meet here in convention because it is going to give me an opportunity for a couple of days off. I have not had very many days off. As a matter of fact, I started last night with some of the delegates to discuss the very important problems which will be discussed here in this convention, and then, when I was probably at the height of my oratory, at 11 o'clock, I got a telephone call that I must leave for Cambridge.

I am certainly glad that you are here, I want you to visit Cambridge, and I wish to assure you that it is a pleasure to renew the acquaintances that I made in this fine organization, whose every effort is in the direction of progress and to do something for New England and for the country. (*Applause.*)

Mr. Weston. Mr. Winsor, it gives me great pleasure at this time to turn the convention over to you. I hope everything will be as successful as the Committee desires it to be. (*Applause.*)

(At this point President Winsor takes the chair.)

President Winsor. It has been a great pleasure to me to have had the words of welcome from the speakers representing the Governor of Massachusetts and the Mayor of Boston and from the Mayor of Cambridge. I have attended quite a number of the meetings of this Association, and I think that this is the first time that the Association has been welcomed by representatives of the State and the cities who have been water-works men.

I presume that most of the men in this room know that, outside of being the representative of the Governor on this occasion, Mr. Keniston is the chairman of the Metropolitan District Commission, which Commission is entrusted with supplying water to this whole Metropolitan District. He is also, by act of the Legislature, chairman of the Metropolitan District Water Supply Commission, whose duty it is to provide a large extension to the Metropolitan System. While he is not an engineer, his knowledge in water-works matters is comparable to that of most engineers and to most of the members of this Association. As an executive in charge of the work of these two State Commissions, I think he has few equals, and I am very much pleased that he represented the Governor at this meeting.

The representative of the city of Boston was a former member of this Association and is an engineer of national standing.

The Mayor of Cambridge, as he said to you, is a former water-works superintendent. I think that engineers and water-works superintendents seldom become mayors, and it is certainly gratifying to have those who do address our conventions. I should like to invite all the speakers — although I think I have previously done so — to attend as many of these

technical sessions as they have opportunity for and in which they might be interested.

We have had an excellent program committee, and I think they have done a very good job. You will perhaps remember the story of the man who refused to have a doctor and got all of his medical advice out of a book, but it is said that he died of a misprint. (*Laughter.*) Now, I don't know that there are any misprints in this program, but there are some necessary changes. I think there is only one paper on the program that is not to be presented. Unfortunately there is also one paper that we are unable to present at this time.

The chairman of the Committee has spoken of the Mayor's cup. I rather regret that the cup was not placed here so that you people could all see it, and I suggest that past President Killam bring it up here for a moment and put it on the table so that you may all look at it. I do not know up to date who is entitled to it. I suggest that perhaps some of you might have friends in London whom you might cable, and they might come across in one of the transatlantic airplanes. There is still time to win the cup.

(Mr. Killam places the Mayor's cup on the President's table.)

The Secretary, Frank J. Gifford, submitted his annual report. (See page 302.)

The Treasurer, Albert L. Sawyer, submitted his annual report. (See page 306.)

The report of the Finance Committee was read by Samuel E. Killam. (See page 309.)

A joint progress report was presented by Frank A. McInnes as chairman of the Committee on Standardization of Cast-Iron Pipe and Special Castings, the Committee on Simplification of Manhole Frames and Covers, and the Committee on Specification for Cast-Iron Pipe and Special Castings. (See page 313.)

The report of the Committee on Standard System of Sanitary Scoring of Water Supplies was presented by E. Sherman Chase. (See page 316.)

PRESIDENT WINSOR. You have heard this very interesting and valuable report together with the recommendations of the Chairman of the Committee that it be adopted in the manner in which he has stated. I would suggest that a motion to that effect will be in order.

(On motion of Mr. George F. Merrill, as amended by Mr. Robert Spurr Weston and duly seconded, it was VOTED that the report be accepted and placed on file, that the recommendation be adopted, that the executive committee consider the advisability and wisdom of having a number of score cards printed and placed on sale, and that the committee be continued to advise on the score cards in practice.)

Progress reports were made by the following committee chairmen: A. O. Doane for the Committee on Painting Standpipes. X. H. Goodnough for the Committee on Yields of Catchment Areas. R. S. Weston

for the Committee on the Effect of Cement-Lined Pipes on Quality of Water. C. W. Sherman for the Legislative Committee. H. W. Clark as Representative at Tests of the Bureau of Standards.

Closing of Polls and Appointment of Tellers.

President Winsor. Under section 4 of Article 7 of the Constitution of the Association, one hour after the opening of the annual convention the polls shall be closed and the president shall appoint a committee of three who shall open and count the ballots cast by the persons entitled to vote. In compliance with the Constitution, I therefore now declare the polls closed, and I ask Mr. George F. Merrill, Mr. Patrick J. Lucey and Mr. Charles J. Crump to act as tellers.

Tuesday, September 13.

Afternoon Session.

The Secretary announced the election to membership of the following: George M. Warren, Washington, D. C.; John T. Robinson, Utica, N. Y.; Carl C. Craig, E. Providence, R. I.; S. L. Briggs, Onset, Mass.; F. Perry Close, East Hartford, Conn.; Elwood L. Dean, Providence, R. I.

Associates: The American Brass Company, Waterbury, Conn.; W. & L. E. Gurley, Troy, N. Y.; General Pipe Cleaning Company, Philadelphia, Pa.; Barber Greene Company, Aurora, Ill.; LaMotte Chemical Products Company, Baltimore, Md.; Giant Manufacturing Company, Council Bluffs, Ia.; National Cast-Iron Pipe Company, New York, N. Y.

A paper on "Water Supplies in New York State and Laws Relating Thereto," was read by C. A. Holmquist, Director, Division of Sanitation, New York State Department of Health.

A progress report of the Committee on Cross-Connections was presented by R. S. Weston.

A paper on "Cross-Connections in Connecticut" was read by Warren J. Scott, Chief Engineer, Connecticut State Department of Health. This paper and the report of the Committee on Cross-Connections were discussed by Robert Spurr Weston, Charles W. Sherman, Henry R. Buck, Charles W. Mowry, Stephen R. Taylor, Harry A. Burnham, M. N. Baker, Charles T. Howard, George F. Merrill, J. E. Gibson, Ezra E. Clark, Theodore L. Bristol, Arthur D. Weston, Samuel A. Agnew, Henry T. Gidley, Hugh McLean, Henry V. Macksey, Percy R. Sanders, Edward E. Barrier and Howard M. King.

A paper on "Leaks and Litigation" was read by George H. Finneran, Superintendent Water Service Department, City of Boston. David A. Heffernan and Percy R. Sanders took part in the discussion.

A progress report of the Committee on Use of Thermit Heat Units on Frozen Hydrants, etc., was presented by Percy R. Sanders.

TUESDAY, SEPTEMBER 13.

Evening Session.

Charles W. Mowry, Assistant Manager, Inspection Department, Associated Factory Mutual Fire Insurance Company, gave a talk on "Fighting Fires Beforehand," illustrated by stereopticon slides. George W. Booth, George A. Carpenter, George A. King, Henry T. Gidley, George F. Merrill, Stephen H. Taylor, H. N. Hunt, J. E. Gibson, W. S. Creamer, Hugh McLean, Henry V. Macksey and Edward E. Barrier participated in the discussion.

Franklin H. Wentworth, Secretary, National Fire Protection Association, gave a talk on "Field Engineering Service of the National Fire Protection Association." The discussion was participated in by Hugh McLean, W. S. Creamer and C. W. Mowry.

WEDNESDAY, SEPTEMBER 14.

Morning Session.

A paper on "Reliability Features of Electrically Operated Pumping Equipment," was read by R. C. Dennett, Office Engineer, National Board of Fire Underwriters. Allen Hazen, A. O. Doane, Charles W. Sherman and Arthur L. Shaw took part in the discussion.

A paper on "Five Years' Operation, Boston High-Pressure Water System," was read by E. E. Williamson, Maintenance Division, Boston Fire Department. Charles W. Sherman, Frank A. McInnes, former Chief Eugene M. Byington, R. C. Dennett and Arthur D. Weston took part in the discussion.

The report of the Editor of the JOURNAL, Gordon M. Fair, was read by the Secretary. (See page 310.)

WEDNESDAY, SEPTEMBER 14.

Afternoon Session.

A paper on the "Montreal Typhoid Epidemic" by Aimé Cousineau, Sanitary Engineer, Department of Health, Montreal, was read by title. The subject was commented upon by M. N. Baker, Abel Wolman and H. P. Eddy.

A paper on "Interstate Water Rights" was read by Caleb M. Saville, Manager and Chief Engineer, Board of Water Commissioners, Hartford, Connecticut.

A paper on "Public Works and State Boundaries," prepared by Clemens Herschel, Consulting Engineer, was read by the Secretary.

The two papers were discussed by Messrs. Theodore L. Bristol, Allen Hazen, J. Frederick Jackson, Charles S. Denman, J. Waldo Smith, X. H. Goodnough, George A. Carpenter, M. N. Baker, Stephen DeM. Gage,

Samuel A. Agnew, Robert Spurr Weston, Charles W. Sherman, David A. Heffernan, H. N. Blunt and Henry T. Gidley.

A paper on "What Every Engineer and Water-Works Superintendent should Know About Chlorination," was read by R. V. Donnelly, General Manager, Paradon Manufacturing Company, Arlington, N. J.

A paper on "Elimination of Errors in the Ortho-Tolidin Method," was read by F. R. McCrumb, Chief Chemist, La Motte Chemical Products Company. This paper was discussed by Edward E. Minor.

Upon motion of Caleb M. Saville it was voted to appoint a Committee on Corrosion of Iron and Steel Pipes and Standpipes.

At 6.30 P.M., a demonstration was given by the Boston Fire Department of the High-Pressure Fire System and of the Fire Boats. This took place on Dorchester Avenue, between the Congress Street and Summer Street bridges.

WEDNESDAY, SEPTEMBER 14.

Evening Session.

A paper on "Amesbury Iron Removal Plant" was read by G. A. Sampson, of Weston & Sampson, Consulting Engineers. A. O. Doane and Allen Hazen discussed the paper.

A paper on "Sand Embankment Impounding Dam, City of Chicopee," was read by Myron G. Mansfield, of Morris Knowles, Inc., Consulting Engineers. Allen Hazen, Edward E. Barrier and Francis B. Marsh took part in the discussion.

A paper on "Municipal Water and Sewerage Costs in Maryland," was read by Abel Wolman, Chief Engineer, Maryland State Department of Health. Allen Hazen, Edward Wright, Caleb M. Saville and M. N. Baker took part in the discussion.

During the progress of the main session, a Special Superintendents' Conference was held in an adjoining room, at which subjects of particular interest to superintendents were discussed. Stephen H. Taylor presided. The practice of providing service lines to vacant lots was particularly discussed, and on motion, duly seconded, it was VOTED that "It is the conclusion of the meeting that the laying of service lines to vacant lots is impractical and should be discouraged."

THURSDAY, SEPTEMBER 15.

Morning Session.

Award of Dexter Brackett Memorial Medal.

PRESIDENT WINSOR. As I suppose most of you know, this Society awards annually what is known as the Dexter Brackett Memorial Medal. This medal was established in memory of Dexter Brackett, who was at one

time president of this Association, and was one of the most prominent engineers identified with the Boston and Metropolitan water supply.

I will ask the chairman of the committee of three members of the Association, which is appointed each year to examine the papers presented, to award this medal. Mr. Allen.

RAYMOND C. ALLEN. The Committee on Award of the Dexter Brackett Memorial Medal for 1926 has carefully examined all the papers and are unanimous in the recommendation that the award be to Mr. Caleb M. Saville for his paper on "Compensation for Stream Diversion for Municipal and Other Supplies."

It seems to me that when a man takes from his busy life the time to gather together the facts and present a valuable paper for the benefit of us all, he lays us under an obligation to him; but when, as in this case, he does that for the second time, it seems that he lays us under the very deepest sort of obligation.

Mr. Saville, on behalf of the Committee and the Association I take great pleasure in presenting you with this medal.

CALEB M. SAVILLE. Thank you, sir. Mr. Chairman and Gentlemen: It was with feelings of very great surprise as well as exceeding pleasure that I received notification that the Dexter Brackett Memorial Medal had been awarded to me for the year 1926.

While the receipt of this medal for the second time is the source of much gratification and most sincerely appreciated, yet it seems somewhat unfair that the honor should again lie on the same shoulders when there are so many others who have worked hard and given of their time and experience for the good of the New England Water Works Association.

Just ten years ago, for a paper read in 1916, the first award of the Dexter Brackett Memorial Medal was made to the present recipient, the presentation being made at that time by Mr. Desmond FitzGerald.

This medal, as you all know, is in recognition of Mr. Brackett's devotion and work in placing this Association in the front of the water-works societies of the world, and it is symbolic of his character — a straightforward, honest man, as well as a leader of the ablest water-works engineers of the country.

In the twelve years that have elapsed since Mr. Brackett's death notable contributions to water supply knowledge have been recorded in papers presented to this Association. Among these matters, those which I believe would have been of most interest to Mr. Brackett are the increasing use of pre-cast reinforced concrete pipe, the development of the steam turbine centrifugal pump, and the manufacture of centrifugally-cast iron pipe.

I feel sure that Mr. Brackett would have viewed with concern the advance in the price of cast-iron pipe, from a low of $17 per ton in 1897 to a high of $81 per ton in 1920. I feel certain, however, that these prices for material and similar advances in labor cost would have been but a spur to

his activity and ingenuity for devising some means of keeping down the resulting cost of construction work.

I hope during the coming years a determined endeavor will be made by members of this Association to present constructive papers on those matters especially pertaining to the particular line of work specialized in by Mr. Brackett.

As for myself, I hope that the medal which you have given me will always be an incentive for better work for the good of the public water supply, and so to keep the faith with those leaders in this branch of our profession who have always been members of this Association — Messrs. Brackett, Stearns, FitzGerald, Metcalf, Whipple and Sedgwick.

I thank you, gentlemen, for your attention and for your generosity.

A paper on "Distribution Pumping Stations of the Metropolitan Water Works" was read by A. O. Doane, Water Division, Metropolitan District Commission. This was discussed by William W. Brush, Samuel H. MacKenzie, Henry T. Gidley and M. N. Baker.

A paper on "The Water Supply of Caracas, Venezuela," was read by Thorndike Saville, Professor of Hydraulic and Sanitary Engineering, University of North Carolina, and Chief Hydraulic Engineer, North Carolina Department of Conservation and Development. Allen Hazen, L. H. Enslow and Richard G. Tyler took part in the discussion.

A paper on the "Standpipe at Charleston, S. C.," was read by J. E. Gibson, Manager and Engineer, Commissioners of Public Works, Charleston, S. C. Alexander Orr and Theodore L. Bristol participated in the discussion.

A paper on "Five Years of Rapid-Sand Filtration at Cambridge, Massachusetts," prepared by Melville C. Whipple, Assistant Professor of Sanitary Chemistry, Harvard Engineering School, Supervising Chemist of Cambridge Water Board, and Harold C. Chandler, Chemist, Cambridge Water Purification Works, was read by Professor Whipple. L. H. Enslow and E. Sherman Chase took part in the discussion.

A paper on "One Year's Operation of the Providence Filtration Plant," prepared by Julius W. Bugbee, City Chemist, and Elwood L. Bean, Resident Chemist, was read by Mr. Bean. Allen Hazen, F. N. Connett, E. Sherman Chase, L. H. Enslow and President Winsor participated in the discussion.

At 2 P.M. the members and guests of the Association left the Hotel Statler for the Cambridge Filter Plant, where they were the guests of the City of Cambridge at a luncheon and at an inspection of the plant.

In the evening a dinner dance was given at the Hotel Statler for members and guests through the courtesy of the Water Works Manufacturers' Association, Inc.

FRIDAY, SEPTEMBER 16.

Morning Session.

A paper on "Clarification of the Catskill Water Supply of the City of New York by Coagulation and Sedimentation" was read by William W. Brush, Chief Engineer, Department of Water Supply, Gas and Electricity, New York City. George W. Fuller, Robert Spurr Weston, Melville C. Whipple, Richard G. Tyler and Arthur B. Morrill took part in the discussion.

(Award of Mayor Malcolm E. Nichols' Trophy for Member coming from Longest Distance.)

PRESIDENT WINSOR. The next matter on the program is the awarding of the Malcolm E. Nichols Trophy for the member coming the longest distance. I do not know whether anyone had authority to make the ruling that the longest distance is to be interpreted as the longest distance as the crow flies. We had one member here who suggested that inasmuch as he had been to Maine three times in the last week, and had had his wife with him, he had traveled farther than the man from Iowa and that he should get the cup, but I understand that he has been turned down and that it is the man who has traveled the farthest distance in reaching Boston on a single trip, by the shortest possible route, who is going to win.

The following information is just now passed to me by the Chairman of the Committee on Arrangements. This says that the four members who have traveled the greatest distances to this Convention are, first, Charles S. Denman, of Des Moines, Iowa; Mr. Denman is general manager of the Des Moines Water Works and has traveled 1 160 miles; second, Anson W. Squires, Superintendent of Water Works, Tampa, Florida; third, J. E. Gibson, Manager and Engineer, Commissioners of Public Works, Charleston, South Carolina; and fourth, W. S. Creamer, Chief Engineer and Superintendent of Water Works, Lexington, Kentucky.

I may say in explanation that this cup was presented by Mayor Nichols to be awarded to the member of the Association who traveled the longest distance to this Convention, and the cup is now in the rear of the room. It is indicative of the coöperation which we have received from the City Authorities of Boston in arranging this convention.

I am extremely sorry that it is impossible to present the cup to the winner at this time, but it will be shipped to him unless he appears to claim it before he leaves Boston.

ELECTION OF HONORARY MEMBERS.

PRESIDENT WINSOR. I will, at this time, announce that the Executive Committee during the past year has elected five honorary members. I think the announcement has been made in the case of at least the first one, and possibly in the case of others.

Clemens Herschel was elected an honorary member early in the year, and later in the year the following were elected honorary members:

F. F. Forbes of Brookline, past president of the Association and long a member; Allen Hazen, a past president; X. H. Goodnough of Boston; J. Waldo Smith of New York, a past president.

Report of Tellers of Election.

Total number of ballots cast	289
President.	
GEORGE A. CARPENTER	284
Blanks and scattering	5
Vice-President.	
ROBERT SPURR WESTON	285
Blanks and scattering	4
Directors.	
GEORGE W. BREHM	278
ROGER W. ESTEY	279
Blanks	21
Treasurer.	
ALBERT L. SAWYER	282
Blanks	7

GEORGE F. MERRILL, *Chairman.*
P. J. LUCEY,
CHARLES J. KRUMP.

PRESIDENT WINSOR. Under the Constitution it is necessary for the President to remain in the chair until the close of this Convention, and therefore it is impossible for me to turn the gavel over to more worthy hands at this time. However, the President-elect is here and, while you all know him, I am going to ask him, not to make an address but just to speak to you. He can deliver a valedictory a year from now. (*Applause.*)

PRESIDENT-ELECT GEORGE A. CARPENTER. Mr. President, I am grateful to the Constitution for not placing the gavel in my hands at this time. I also thank you for your consideration in not demanding a speech.

I simply bespeak from the Association your support and help during the coming year to the officers-elect. This Association will be what you help to make it. Your officers will do their best, but they cannot make a success without your assistance. I thank you. (*Applause.*)

The Secretary announced the election of the following new members: Arthur B. Morrill, Detroit, Mich.; Andrew W. P. Cobb, Auburn, Me.; Florence E. Driscoll, Haverhill, Mass.; John P. Lynch, Somerset, Mass.; John Hollis Read, Manchester, N. H. *Associates:* Chicago Bridge & Iron Works, New York City, N. Y.; The Federal Meter Corporation, East Orange, N. J.

Mr. Charles W. Sherman. Mr. President, I want to move that the President and Secretary be instructed to send a message of greeting in the name of the Association to our past president and honorary member, Mr. Frank E. Hall. Mr. Hall was a charter member of the Association, being now the only surviving charter member, and was its second president. Many of the younger members may not know Mr. Hall, but the older ones all do. I understand that Mr. Hall's physical condition may be called good, but that he is practically confined to the house. I am sure he will appreciate the message, and I think it would be a misfortune if this Convention should adjourn without sending such a message.

(*The motion was duly seconded and carried.*)

President's Address.

President Winsor. The Constitution of the New England Water Works Association requires the retiring president to deliver an address at the Annual Convention, and, in compliance with this requirement, the speaker has somewhat casually scanned the changes in the water supplies of the Metropolitan District of Boston during the last forty-five years, or since the year 1882, when this Association was formed.

Water-works engineering was little beyond the kindergarten stage in 1882. Boston had a water supply from 1796, first from Jamaica Pond and later mainly from Cochituate Lake in 1848, supplemented by the Sudbury River sources in the early nineties. Cambridge was first supplied by Fresh Pond in 1856; Charlestown, Somerville, Chelsea and Everett in 1867 from Upper Mystic Lake; and from 1870 to 1882, in which latter year this Association was organized, water supplies were introduced in the order named, in Medford, Melrose, Lynn, Malden, Arlington, Waltham, Woburn, Brookline, Saugus and Newton. From 1882 to 1885, Wakefield, Stoneham, Lexington, Quincy, Revere, Winthrop, Hyde Park, Watertown and Belmont were supplied.

According to the census of 1885, about 700 000 people, in what is now the Metropolitan Water District which includes approximately the area within ten miles of the State House, enjoyed in that year, public water supplies furnished by more than twenty different agencies, municipally or privately owned. The population of the corresponding communities at this time is approximately three times that of 1885.

The various municipalities were growing rapidly in the late eighties, and it became evident that a community of interests must be established in order to provide at a reasonable expense water of suitable quality and quantity necessary to provide for the rapidly increasing needs of the district, and without which continued growth would be impossible. The State Board of Health in 1895, after an exhaustive investigation under the leadership of the late Frederic P. Stearns, long a leading member of this Association and one of the ablest hydraulic and water supply engineers of his time,

reported to the Legislature, recommending a system of metropolitan water supply. The necessary legislation was passed in that year, and within ten years an adequate supply, mainly from Wachusett Reservoir, was available for such parts of the Metropolitan District as then required it.

Briefly, the Metropolitan Water System is a consolidation into a single system of collecting and distributing works under a state commission of such of the sources of water supply as were in 1895 considered from the standpoint of quality and quantity to be most suitable for common use. This commission, first known as the Metropolitan Water Board, was appointed in 1895 and shortly thereafter took over the collecting works of the city of Boston, including Chestnut Hill Reservoir, the aqueducts from Chestnut Hill to Lake Cochituate and the Sudbury River at Framingham, Lake Cochituate, the various Sudbury reservoirs, and the Mystic Lake supply, later abandoned as a water supply. Spot Pond and other works of less importance were taken from other municipalities. The various municipalities from which works were taken were compensated therefor from funds obtained by assessments upon the portions of the Metropolitan District using Metropolitan water.

The present successor to the original Metropolitan Water Board, known as the Metropolitan District Commission, controls, therefore, the collecting reservoirs,—Wachusett Reservoir, Sudbury reservoirs, Lake Cochituate, etc.; the aqueducts, Wachusett, Weston, Sudbury and Cochituate; the distributing reservoirs, Chestnut Hill, Spot Pond, etc.; and such main distribution pipes throughout the district as are required to deliver water in wholesale quantities to the various municipalities using it. The Metropolitan Water System has nothing to do with the local distribution of water and collection of revenue within the respective municipalities, this being a function of the local authorities, nor is any municipality forced by legislation to take Metropolitan water or to pay therefor before the time when, generally due to the fact that its other sources of supply become inadequate in quality or quantity, it chooses to enter the district.

Coincident with the taking-over of the existing works, the Metropolitan Water Board began in 1895 the construction of the Wachusett Reservoir and aqueducts, which reservoir after completion became and still is the main source of supply of the Metropolitan District. It was believed in 1895, that the Wachusett Reservoir would be sufficient for the needs of the district until 1915, and shortly after that time, in 1919, the need for the next main addition to the system became so evident that a joint board consisting of the State Department of Public Health and the Metropolitan District Commission was instructed by the Legislature to investigate and report upon water supply extension, which they did in 1922. No immediate action was taken upon this report, and the Legislature authorized another investigation under a special committee, which investigation was covered by a report made in 1926. After consideration of these two reports, the Legislatures of 1926 and 1927 provided for an additional supply from the

Ware and Swift rivers, along lines closely following the recommendations of the joint board of 1922, which development was previously, in 1895, suggested by Mr. Stearns as the next step to follow the complete utilization of the Wachusett Reservoir.

The construction of the new works was entrusted to a new commission known as the Metropolitan District Water Supply Commission, with the provision that the works, when completed, be turned over to the Metropolitan District Commission for operation.

The forty-five years which have elapsed since this Association was formed have witnessed these many changes in the water supplies of Boston and vicinity, and such changes are typical of the entire country. At this time, owing, in considerable part, to the financial and other uncertainties following the World War, many communities have water supplies inadequate to their needs, and the next decade will require unusual activity in water supply extension throughout the country.

The extension of the Boston Metropolitan System now under way is estimated to cost $65 000 000; New York City must soon enter upon a project to cost one-fourth of a billion dollars; Los Angeles has a large project in prospect for taking a new water supply from the Colorado River; Philadelphia must soon make major additions to its system; and smaller communities throughout the country in countless numbers must proportionately add to their water supply resources.

It is interesting to note the changes which have occurred in the membership since forty-five years ago a small group of men with vision founded this Association. Only one of these original members is now on the roll of membership. Of a total membership of about eight hundred, only three per cent. joined prior to 1890 and only eleven per cent. prior to 1900.

The Association has done much for its members and for the advancement of water supply standards, not only in New England, but throughout the country, and even throughout the world. It has a promising future before it, and, in coöperation with similar organizations, should be a strong influence in disseminating knowledge and in encouraging a degree of fraternity among water-works men, which is most essential to their happiness and to their best service to their respective communities.

In closing, I want to express my appreciation for the kind treatment that the Executive Committee and the Association have accorded me during the last year. Coming to Boston about October 1, last year, the job of president of this Association looked rather formidable, and for a time I was rather at sea, but fortunately some of the members of the Executive Committee — I might say *all* the members of the Executive Committee — helped in every way possible. I want particularly to express my obligation to the Secretary, and also my very great obligations to Arthur Weston, who took upon himself the chairmanship of the Committee on Papers, and not only the chairmanship, for he did the whole job. I don't know whether we would have had any meetings or any papers if it had not been for him.

There is frequently help available for a drowning man, but whether there would have been anybody else who would have seen that I was going down, if Arthur Weston had not been around, I do not know. He responded, and he stayed on the job. He is also chairman of the Convention Committee, and the whole committee has been a wonderful committee. But Arthur Weston has been the general in charge, he has taken the responsibility, and I want to thank him for all he has done to make this Convention what I consider to be a successful convention.

We have had wonderful coöperation from the Governor's office, from the mayors of the City of Boston and the City of Cambridge, from the Hersey Manufacturing Company, which has helped us in many ways, both in our registration and in entertaining us at their factory, as well as in other ways which I do not need to mention. The Manufacturers' Association has coöperated with us in every way that we could expect.

There are one or two other matters that I want to mention. The Association has had a healthy year. We have practically held our membership. We have not increased, but we have not made any drive for membership.

It has been a great pleasure to me to have had papers presented here by two of our members who are also officers in the American Water Works Association. One of these papers was read by Mr. Gibson, the President of the American Water Works Association, who I believe is attending a meeting of this Association for the first time, having come all the way from South Carolina for that particular purpose. While I cannot express regret that he has not won the cup, I can say that I wish we had had cups for all those who came from great distances. The other paper was presented by Mr. Brush, who I believe is senior vice-president of the American Association. The relations between the American Water Works Association and the New England Water Works Association have always been cordial, and I hope that as time goes on they may become even more so.

I wish to express my best wishes to the incoming administration, and to congratulate you upon getting someone to fill the office of president other than the present encumbent. I thank you. (*Applause.*)

Is there any other matter of business to bring before the meeting before the Convention adjourns?

THEODORE L. BRISTOL. Mr. President, I would like to submit the following resolution:

Resolved, that the thanks of the New England Water Works Association are hereby extended to His Excellency Alvan T. Fuller, Governor of the Commonwealth of Massachusetts; to His Honor Malcolm E. Nichols, Mayor of Boston; to His Honor Edward W. Quinn, Mayor of the City of Cambridge; to the Honorable Davis B. Keniston, Metropolitan District Commissioner; to Dr. George H. Bigelow, Commissioner of Public Health of the Commonwealth of Massachusetts; to Francis X. Mahoney, Commissioner of Health, City of Boston; to John H. Sullivan, Commissioner of Public Works, City of Boston; to Eugene C. Hultman, Fire Commissioner

of the City of Boston; to E. E. Williamson, Superintendent of the Maintenance Division of the High Pressure System of Boston; to Chief Sennott and his Deputy-Chiefs of the Boston Fire Department, and to others of the City of Boston, the City of Cambridge and nearby cities for their cordial welcome and the many courtesies which they have extended to the Association at this Forty-sixth Annual Convention.

ARTHUR D. WESTON. Mr. President, I would like to submit the following resolution:

Resolved, that the thanks of the New England Water Works Association be extended to the Water Works Manufacturers' Association, the Hersey Manufacturing, Metcalf & Eddy, our member consulting engineers, the contractors, the Hotel Statler and their able officers, for the very splendid entertainment which they were able to give us at the Forty-sixth Annual Convention.

GEORGE A. CARPENTER. Mr. President, I would like to submit the following:

Resolved, that the thanks of the New England Water Works Association are hereby extended to Mrs. Adams Tolman and Mrs. William Wheeler, who acted as guides and in other ways contributed to the interest and pleasure of the entertainment of our ladies on their trip to Concord and Lexington at this our Forty-sixth Annual Convention.

(The three motions were duly seconded and unanimously carried.)

THEODORE L. BRISTOL. I move that the Convention be dissolved.

(The motion was duly seconded and carried.)

(*Adjourned.*)

At 12.15 P.M. the members and guests sailed down Boston Harbor for a shore dinner and dancing at the Hotel Pemberton, Hull. This was through the courtesy of the Water Works Manufacturers' Asssociation, Inc.

ANNUAL REPORT OF THE SECRETARY.

Mr. President and Gentlemen of the New England Water Works Association,—The Secretary submits herewith the following report of the changes in membership during the past fiscal year, and the general condition of the Association.

The present membership is 783, constituted as follows: 11 Honorary, 673 Members, 1 Junior, 87 Associates, 11 Corporate Members. The detailed changes are as follows:

MEMBERSHIP.

September 1, 1926.	Honorary Members		8		
	Withdrawals:				
	Died	1	1	7	
	Elected:				
	June, 1927			4	11
September 1, 1926.	Total Members		682		
	Withdrawals:				
	Transferred to Honorary List	4			
	Resigned	24			
	Dropped	14			
	Died	15	57	625	
	Elected:				
	September, 1926	23			
	November, 1926	2			
	December, 1926	2			
	January, 1927	2			
	February, 1927	2			
	March, 1927	4			
	June, 1927	3			
	August, 1927	1	39		
	Reinstated:				
	Dropped in 1902	1			
	Dropped in 1919	1			
	Resigned in 1922	1			
	Dropped in 1924–25	2			
	Dropped in 1925–26	2	7		
	Transferred from Junior List	1			
	Elected 25–26, qualified 26–27	1	2	48	673
September 1, 1926.	Total Juniors		2		
	Transferred to Members List		1		1
September 1, 1926.	Total Associates		87		
	Withdrawals:				
	Resignations	2			
	Dropped	3	5	82	
	Elected:				
	November, 1926	2			
	January, 1927	1			
	August, 1927	2		5	87
September 1, 1926.	Total Corporates		6		

Elected:			
September, 1926	2		
November, 1926	1		
June, 1927	1	4	
Elected 25–26, qualified 26–27	1	1	11
September 1, 1927. Total Membership			783
September 1, 1926. Total Membership			785
Net loss			2

Members Elected from September 1, 1926, to September 1, 1927.

Honorary Members.

June 21, 1927. Transferred from Members List: F. F. Forbes, X. H. Goodnough, Allen Hazen, J. Waldo Smith. (4)

Members.

September 14 to 17, 1926. E. H. Arnold, F. W. Cotter, G. D. Dane, G. C. Danforth, O. J. Eagan, C. E. Gardner, Alfred Gildersleeve, G. L. Hathaway, G. E. Hawkins, F. E. Hussey, F. W. King, F. H. Kingsbury, M. J. Mahoney, W. E. Merrill, A. P. Murray, M. B. Palmer, Malcolm Pirnie, E. L. Randall, G. B. Raymond, William Storrie, A. W. Squires, R. H. White, T. F. Wolfe. (23)
November 10, 1926. S. P. Gates, W. A. Kennedy. (2)
December 8, 1926. C. W. Mowry, A. M. Symonds. (2)
January 12, 1927. J. D. Capron, S. S. Anthony. (2)
February 9, 1927. W. H. Sears, H. B. Crowell. (2)
March 8, 1927. C. D. Abbott, F. W. Gow, Andred Koch, F. H. Rose. (4)
June 21, 1927. C. O. Murphy, E. F. Putnam, J. W. Wattles, 3rd. (3)
August 5, 1927. P. W. Mack. (1)

Reinstated:			
Dropped in 1902. J. W. Shippee	1		
Dropped in 1919. Hugh Nawn	1		
Resigned in 1922. E. T. McDowell	1		
Dropped in 1924–25. J. A. Handy, H. C. Kerr	2		
Dropped in 1925–26. C. W. Ellis, Jr., M. J. Rutledge	2	7	
Elected in 1925–26, qualified 1926–27. W. H. Powell	1		
Transferred from Junior List: E. T. Killam	1	2	9

Corporate Members.

September 14 to 17, 1926. Glens Falls (N. Y.) Board of Water Commissioners, Quincy (Mass.) Water Department. (2)
November 10, 1926. Rockville (Conn.) Water & Aqueduct Co. (1)
June 21, 1927. Reading (Penn.) Bureau of Water. (1)
Elected 1925–26, qualified 1926–27: Kingston (Mass.) Water Commissioners. (1)

Associate Members.

November 10, 1926. A. W. Chesterton Company, Morgan B. Main. (2)
January 12, 1927. Layne New York Co. (1)
August 5, 1927. Automatic Hose & Coupling Company, Michigan Valve & Foundry Company. (2)

Honorary Members.

Died: Desmond FitzGerald. (1)

Members.

Died: M. N. Brondson, A. S. Corr, F. H. Crandall, F. L. Cushing, W. D. Frederick, J. M. Goodell, E. A. W. Hammatt, F. C. Kimball, F. A. Mazzur, F. A. McClure, J. W. Mead, J. F. O'Connor, Dr. F. C. Thayer, C. E. Warren, C. R. Wood. (15)

Resigned: J. C. Adams, Jules Breuchaud, C. L. Crosier, F. J. Davis, L. E. Dix, C. A. Farnham, W. E. Foss, C. L. Fox, H. F. Frost, W. A. Gardner, W. R. Gelston, C. T. Hatton, W. B. Jones, James Laurin, J. Y. Lavery, W. B. R. Mason, E. L. H. Meyer, J. L. Morton, H. W. Stevenson, A. T. Thompson, D. H. Townley, K. Q. Volk, R. F. Wagner, A. L. Webster. (24)

Dropped: F. L. Buckley, H. R. Cooper, C. B. Cruger, C. W. Ellis, Jr., M. G. Ferry, C. C. Gerrich, F. E. Hartman, C. B. Hayward, Thomas Henderson, J. C. Herr, R. E. Manson, J. D. Moore, J. L. Purcell, M. J. Rutledge. (14)

Associate Members.

Resigned: Lawrence Machine Company, United Brass Mfg. Co. (2)

Dropped: Dyar Sales Company, Payne Dean Ltd., Resisto Pipe Co. (3)

Receipts for Fiscal Year, September 1, 1926, to September 1, 1927.

Entrance Fees			$201.00
Annual Dues:			
Members	$3 135.79		
Juniors	3.00		
Associates	1 160.00		
Corporates	90.00	$4 388.79	
Fractional Dues:			
Members	$60.00		
Associates	30.00		
Corporates	7.50	97.50	
Past Dues		188.50	
Prepaid Dues (1927–1928):			
Members	$913.00		
Associates	640.00		
Corporates	20.00	1 573.00	
Total Dues			$6 247.79
Advertisements			4 617.00
Subscriptions			488.08
JOURNALS sold			179.25
Sundries			1 139.62
Total receipts			$12 872.74
There is due the Association:			
Advertisements		$193.00	
Subscriptions		24.00	
JOURNALS		9.45	
Filtration forms		1.20	227.65
Total			$13 100.39

Respectfully submitted,

FRANK J. GIFFORD, *Secretary.*

Annual Report of the Treasurer.

September 1, 1926, to August 31, 1927.

The President and Members of the New England Water Works Association:

I herewith submit my report as treasurer for the year ending August 31, 1927.

Receipts.

September 1, 1926 — Cash on hand			$175.89
Initiation fees	$201.00		
Dues	6 247.79	$6 448.79	
Interest and dividends		674.28	
Journal:			
Advertisements	$4 617.00		
Subscriptions	488.08		
Sale of Journals	179.25		
Sale of reprints	389.25	5 673.58	
Miscellaneous:			
Certificates of membership	$6.00		
Filtration forms	5.40		
Membership lists	3.00		
Standard specifications	6.00		
B.S.C.E. acct. June outing	54.54		
Sundries	1.15	76.09	
Total receipts			12 872.74
			$13 048.63

Expenditures.

Journal:			
Advertising agent's commission	$128.00		
Editor's salary	275.00		
Editor's expense	22.00		
Plates	401.24		
Printing	3 507.09		
Reporting	334.68		
Reprints	885.43		
Stationery and postage	157.77		
Sundries	3.15	$5 714.36	
Office:			
Affiliated Technical Societies	$2 000.00		
Printing stationery and postage	331.67		
Secretary's salary	200.00		
Secretary's expense	128.44		
Sundries	6.80	2 666.91	

Meetings and Committees:			
Dinners for guests	$47.00		
Badges	26.25		
Printing, stationery and postage	645.88		
Stereopticon	35.00		
Share of expense, Pipe Committee	400.00		
Sundries	65.86	1 219.99	
Miscellaneous:			
Certificates of membership	$8.90		
Exchange	1.70		
Treasurer's salary and bond	62.50		
Sundries	98.97	172.07	
Total expenditures			$9 773.33
August 31, 1927 — Cash on hand			3 275.30
			$13 048.63

Invested Funds.

Invested funds September 1, 1926			$13 622.43
Interest on bonds	$80.00		
Interest on deposits	38.00		
Interest on savings bank deposits	556.28		674.28
			$14 296.71
Interest paid over to the Association			$674.28
Invested funds August 31, 1927			13 622.43
			$14 296.71

The Finance Committee for the fiscal year ending August 31, 1927, recommended a budget of $10 500.00.

There has been expended during the year $9 773.33 leaving an unexpended balance of $726.67. The details are as follows:

	Journal.	Office.	Meetings.	Miscellaneous.
Appropriation	$7 000.00	$2 600.00	$700.00	$200.00
Transferred from	586.90	.....	.....	.....
	$6 413.10	$2 600.00	$700.00	$200.00
Transferred to	.....	66.91	519.99	.....
	$6 413.10	$2 666.91	$1 219.99	$200.00
Expended	5 714.36	2 666.91	1 219.99	172.07
Balance	$698.74	.....	.....	$27.93

Respectfully submitted,

ALBERT L. SAWYER, *Treasurer.*

TREASURER'S REPORT.

STATEMENT OF RECEIPTS AND EXPENDITURES.

Receipts.		*Expenditures.*	
Cash on hand September 1, 1926	$175.89	Bills paid as per vouchers	$9 773.33
Interest on bonds and deposits	674.28	Cash on hand August 31, 1927	3 275.30
Received from Secretary	12 198.46		
	$13 048.63		$13 048.63

ASSETS AND LIABILITIES.

Assets.			*Liabilities.*	
Cash in banks as per list		$15 082.73	Surplus	$17 125.38
Old Colony Trust Co.	$3 275.30			$17 125.38
Farmers and Mechanics Savings Bank, Framingham	2 068.46			
Franklin Savings Bank	2 000.00			
Home Savings Bank	1 011.25			
Mechanics Savings Bank	261.19			
People's Savings Bank	1 466.53			
Haverhill Savings Bank	2 000.00			
City Five Cents Savings Bank	1 500.00			
Pentucket Savings Bank	1 500.00			
Bonds Nos. 2642 and 2644 Lake Shore & Michigan So. R.R. 4's due May 1, 1931		1 815.00		
Accounts Receivable		227.65		
Advertisements	193.00			
JOURNALS	9.45			
Subscriptions	24.00			
Filtration forms	1.20			
		$17 125.38		

Report of Finance Committee.

Executive Committee,
New England Water Works Association.
Gentlemen:

The Finance Committee submits the following budget for the fiscal year ending August 31, 1927:

	Expended. 1926–27.	Recommended. 1927–28.
Journal	$5 714.36	$7 000
Office	2 666.91	2 600
Meetings and Committees	1 219.99	800
Miscellaneous	172.07	200
	$9 773.33	$10 600

For the fiscal year just ended the Treasurer has included in his balance as of September 1, 1927, 1927–28 dues received prior to September 1, amounting to $1 573.00.

The amount to be paid to the Affiliated Technical Societies of Boston for dues and charges as a member society for the year ending May 31, 1928, is $2 000, which is the same as the last fiscal year.

The amount assessed the Association in 1927 as a member of the Sectional Committee on Specifications for Cast-Iron Pipe was $400 and paid during the fiscal year just ended under budget item Meetings and Committees.

In lieu of printing the Constitution and List of Members during the coming year we recommend that a list of additions to and resignations from the membership of the Association since the last publication be printed on perforated sheets in one of the Journals and that additional sheets be printed and added to the copies of lists now on hand.

The budget provides $7 000 for the publication of the Journal and as a majority of our members derive most of their benefits from this publication we again recommend that it be still further expanded.

We recommend that $2 000 of the cash on hand at the end of the fiscal year be transferred to the invested funds.

Respectfully submitted,

SAMUEL E. KILLAM,
GEORGE A. SAMPSON,
DWIGHT L. AGNEW.

Annual Report of the Editor.

To the New England Water Works Association: The Editor submits herewith the following report for the year ending August 31, 1927.

As has been customary in the past, the tables of financial figures, accompanying the report, are based upon total charges and accounts receivable, rather than actual cash received or disbursed.

Table 1 is a statement of the material published.

Table 2 gives the receipts and expenditures for the year.

Table 3 is a comparison of the Journal for the past year with preceding years.

Size. The four issues contained 724 pages, of which 492 were text.

Cost. The gross cost of the Journal was $5 839.36, equivalent to $7.45 per member, and, the net cost was $710.63, equivalent to $0.91 per member.

Reprints. Fifty reprints of each paper have been furnished to the author where desired.

Circulation. The present circulation of the Journal is:

Members, all grades	783
Subscribers	120
Exchanges	13
Total	916

(Journals have been sent to all subscribers.)

Respectfully submitted,

GORDON M. FAIR, *Editor.*

EDITOR'S REPORT.

TABLE I.

Statement of Material in September and December, 1926, and March and June, 1927, Issues of the Journal of the New England Water Works Association.

Date.	Pages of								
	Papers.	Proceedings.	Total Text.	Index.	Advertisements.	Cover and contents.	Insert plates.	Total.	Total cuts.
September, 1926	140	35	175	0	51	5	0	231	30
December, 1926	129	4	133	6	51	5	1	196	19
March, 1927	79	3	82	0	51	5	1	139	6
June, 1927	102	0	102	0	50	5	1	158	22
Total	450	42	492	6	203	20	3	724	77

TABLE II.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF SEPTEMBER AND DECEMBER, 1926, AND MARCH AND JUNE, 1927, ISSUES OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Receipts.		*Expenditures.*	
Advertisements	$4 056.00	Advertising agent's salary and commissions	$128.00
Sale of JOURNALS	178.20	Plates	401.24
Sale of Reprints	389.25	Printing	3 507.09
Subscriptions	504.08	Reporting	334.68
Sale of Filtration Forms	1.20	Mailing and postage	157.77
	$5 128.73	Editor's salary	400.00
Net Cost of JOURNAL	710.63	Editor's incidentals	22.00
		Reprints	885.43
		Sundries	3.15
	$5 839.36		$5 839.36

EDITOR'S REPORT.

TABLE III.

COMPARISON OF JOURNALS OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. XXX. 1916.	Vol. XXXII. 1918.	Vol. XXXIII. 1919.	Vol. XXXIV. 1920.	Vol. XXXV. 1921.	Vol. XXXVI. 1922.	Fiscal Year Ending Aug. 31, 1924. 4 issues.	Fiscal Year Ending Aug. 31, 1925. 4 issues.	Fiscal Year Ending Aug. 31, 1926. 4 issues.	Fiscal Year Ending Aug. 31, 1927. 4 issues.
Average edition (copies printed)	1 500	1 388	1 200	1 130	1 150	1 100	1 100	1 100	1 100	1 100
Average membership	1 002	954	902	885	864	826	764	755	775	784
Circulation at end of year	1 155	1 010	1 002	970	929	929	880	873	906	916
Pages of text	538	398	566	359	399	618	404	421	523	492
Pages of text per 1 000 members	538	417	627	406	462	748	529	558	675	628
Total pages, all kinds	707	557	726	520	560	801	611	644	761	724
Total pages per 1 000 members	707	584	805	588	648	970	800	853	982	925
GROSS COST:										
Total	$3 386.63	$3 115.00	$4 967.99	$5 011.03	$5 381.84	$6 354.10	$4 783.60	$5 272.91	$6 524.62	$5 839.36
Per page	4.79	5.59	6.84	9.64	9.61	7.93	7.83	8.19	8.57	8.07
Per member	3.38	3.26	5.51	5.66	6.23	7.69	6.26	6.98	8.42	7.45
Per member per 1 000 pages	4.79	5.85	7.59	10.88	11.12	9.60	10.25	10.84	11.07	10.29
Per member per 1 000 pages text	6.30	8.19	9.74	15.77	15.61	12.47	15.50	16.58	16.10	15.13
NET COST:										
Total	$1 171.98	$694.54	$2 675.04	$1 722.14	$1 869.85	$2 434.26	$561.51	$943.40	$2 040.28	$710.63
Per page	1.65	1.25	3.68	3.31	3.34	3.04	0.92	1.46	2.68	.98
Per member	1.17	.73	2.97	1.95	2.16	2.95	0.74	1.25	2.64	.91
Per member per 1 000 pages	1.65	1.31	4.09	3.75	3.87	3.68	1.20	1.94	3.47	1.26
Per member per 1 000 pages text	2.17	1.83	5.25	5.43	5.43	4.77	1.82	2.97	5.05	1.85

PROGRESS REPORT ON "SPECIFICATIONS FOR CAST-IRON PIPE AND SPECIAL CASTINGS," "PIPE FLANGES AND FITTINGS" AND "MANHOLE FRAMES AND COVERS."

BY FRANK A. McINNES.*

The three matters upon which I am called to report are standardization projects now being developed by the American Engineering Standards Committee. With your permission I will briefly outline the procedure under which such work is carried to completion.

The A. E. S. C. is a national organization with executive authority vested in its Main Committee on which are represented seven departments of the Federal Government, nine national engineering societies and sixteen national industrial organizations. The committee undertakes work on a project only upon a formal request for action by an interested body, and after it is satisfied that a real demand for the requested standard exists.

The Main Committee designates a single sponsor or two or more sponsors representing a body or bodies particularly interested in the proposed standard.

The sponsor organizes the Sectional Committee, sees that its work is effectively prosecuted and provides for the publication of the standard. The personnel of the Sectional Committee consists of the principal interested bodies.

The Sectional Committee formulates the standard and, when agreement is reached, submits it through the sponsor to the Main Committee for approval.

The status of the three standardization projects above referred to is as follows:

Specifications for Cast-Iron Pipe and Special Castings.

Sponsors: American Gas Association, Represenative W. C. Morris; American Society for Testing Materials, Representative C. L. Warwick; American Water Works Association, Representative, F. A. Barbour; NEW ENGLAND WATER WORKS ASSOCIATION, Representative, F. A. McInnes.

The Sectional Committee was organized in April, 1926; it consists of 39 members, classed as 19 Consumers, 7 General Interests and 13 Producers, representing the following 23 organizations: American Gas Association, American Petroleum Institute, American Railway Engineering Association, American Society of Civil Engineers, American Society of Mechanical Engineers, American Water Works Association, American Society for Testing Materials, Canadian Engineering Standards Association,

*Chairman of the Committees.

NEW ENGLAND WATER WORKS ASSOCIATION, Manufacturers Standardization Society of the Valve and Fittings Industry, National Fire Protective Association, Underwriters Laboratories, U. S. Bureau of Standards, American Cast Iron Pipe Co., J. B. Clow & Sons, Glamorgan Pipe and Foundry Co., Lynchburg Foundry Co., National Cast Iron Pipe Co., R. D. Wood & Co., Warren Foundry and Machine Co., U. S. Cast Iron Pipe and Foundry Co., Central Foundry Co., Donaldson Iron Co.

The following officers and executive committee were elected to serve two years: Thomas H. Wiggin, *Chairman*, N. F. S. Russell, *Vice-Chairman*, C. C. Simpson, Jr., *Secretary*.

Executive Committee. The above named officers, together with F. A. Barbour, W. W. Brush, A. M. Campbell, W. D. Moore, C. W. Sherman, C. L. Warwick, Kent S. Clow, W. C. Morris.

The work of the Sectional Committee is divided among three Technical Committees, as follows:

Technical Committee 1 (with 4 sub-committees). On Dimensions.

Technical Committee 2 (with 4 sub-committees). On Metallurgy, Processes and Tests.

Technical Committee 3 (with 6 sub-committees). On Corrosion and Protective Coatings.

A number of particularly qualified men who are not members of the Sectional Committee are serving on the Technical Committees and sub-committees. Time does not permit to go further into the details of the committee work; suffice it to say that the subject is being considered most exhaustively by committees whose personnel is country-wide.

I am informed by President Wiggin that the foundry representatives have agreed to supply the sum of $22 000 for a year's program, and that the expectation is that a similar amount will be authorized next year, if results warrant this further expenditure.

Mr. Wiggin further advises that agreements have been entered into tentatively, and it is expected that formal agreements will be soon ratified with Iowa State College and with the University of Illinois for experiments respectively on trench loads and the trying of Talbot tests on 20-in. pipe.

An agreement has been entered into with the Massachusetts Institute of Technology to proceed with theoretical investigations into the causes of corrosion in cast-iron pipe, with the idea of determining, among other things, the qualities of cast iron that resist corrosion. Money for this investigation was quickly guaranteed under the encouragement of the initial generosity of Mr. Russell who started the fund with $1 000.

Substantial progress has been made in committee work and all committees will be expected to submit a written report for the next annual meeting in March, 1928.

Pipe Flanges and Fittings.

Sponsors: American Society Mechanical Engineers, Heating and Pumping Contractors National Association, Manufacturers Standardization Society of the Valves and Fittings Industry.

The Sectional Committee consists of 61 members classed as 33 Consumers, 9 General Interests and 19 Producers, representing 26 organizations, and 2 departments of the Federal Government, with 8 independent experts.

The standards for steel flanges and flanged fittings for maximum pressures of 250, 400, 600, 900 and 1 350 lbs. have been formulated by the Sectional Committee, approved by the A. E. S. C. in July, 1927, and are now on sale.

The cast-iron flanges and flange fittings for maximum pressures of 125 lbs., cast-iron flanges and flange fittings for maximum pressures of 250 lbs., malleable screwed fittings for maximum pressures of 150 lbs. and cast-iron screwed fittings for maximum pressures of 125 and 250 lbs. have been formulated by the Sectional Committee and are now before the A. E. S. C. for approval as Tentative American Standards.

The cast-iron flanges and flange fittings for maximum pressures of 25 lbs. are being voted upon by the Sectional Committee.

Cast-iron long turn sprinkler fittings and ammonia fittings are being worked on by the sub-committee but are not yet available.

Manhole Frames and Covers.

Sponsors: American Society of Civil Engineers Telephone Group.

The Sectional Committee consists of 28 members classed as 13 Consumers, 9 General Interests and 6 Producers, representing 20 organizations including the Division of Simplified Practice, Department of Commerce and the Bureau of Standards, Washington, D. C.

This project is being actively prosecuted by the Sectional Committee.

REPORT OF COMMITTEE ON A SYSTEM OF SANITARY SCORING OF WATER SUPPLIES.

Authorization. The Committee on a System of Sanitary Scoring of Water Supplies was appointed by the Executive Committee subsequent to authorization by vote of the Association at its 1925 annual convention.

Progress Report of 1926. In 1926 the Committee presented a progress report, in which was given a tentative outline for a score system. This system was not recommended for adoption but was suggested as the basis for further study. The Committee was continued and now presents its final report:

Statement of Problem. It has long been felt by many workers in the water-works field, that some method for applying a quantitative measure to the quality of water supplies was desirable as an aid in judging their relative safety from the viewpoint of public health.

In every water-works project there are three major considerations:

First — The quantity of water available,

Second — The quality of the water,

Third — The financial features of the project.

The first and third considerations are susceptible of reasonably accurate mathematical analysis, but the second consideration has been dealt with usually in general and more or less indefinite terms only. The establishment of a system of sanitary scoring of water supplies is, therefore, an attempt to obtain a quantitative expression of water-supply quality.

Work of Committee. The work of the Committee has been carried on largely by correspondence. Letters have been sent to engineers and others connected with State Health Departments, requesting comments and suggestions with respect to scoring water-supply quality and also requesting that one or more water supplies be scored by them and the results transmitted to the Committee. Letters were also sent to a number of water-works superintendents, members of this Association, making substantially the same request.

As a result of the Committee's requests, criticisms and suggestions have been received from a number of engineers and superintendents, together with the scores of several supplies.

Results of Scoring. The results of the application of the score system, tentatively suggested in the progress report, indicate that relatively little difficulty was experienced in such application. In a few cases the scoring of the same supply was done by two or more individuals independently,

and reasonably close checks were obtained. In those cases where sufficiently detailed data accompanied the scores, the Committee prepared an independent score.

Criticisms and Suggestions. As was expected and desired, numerous criticisms and suggestions were received. A few voiced objections to the attempt to assign numerical values to intangible qualities; others approved. Most had suggestions to make. Among the more severe criticisms are the following:

The Director of the Bureau of Sanitary Engineering of a Western State, wrote that, in his opinion, the score system, as outlined, was entirely too indefinite; that the results would be clearly misleading, and that the score system on its face was bound to be arbitrary. He did, however, state that if enough people finally determined on relative values it ought to be reasonably indicative for comparative purposes in a broad way.

The chief engineer of another State wrote: "Frankly I do not favor numerical scoring of water supplies because there are too many items for which values have to be assigned, and then when the scoring is finally completed it is necessary to go back into the written statements to find out just what is wrong with the supply. It is my impression that the numerical score of dairies is less used now than it formerly was used, especially where trained inspectors or milk sanitarians are functioning. I believe that an outline covering all points that should be checked in connection with the sanitary inspection of a water-supply system, without numerical values, would be better than trying to use numerical values. Then for each item there could be indicated O. K., N. G., Fair; and where the item was not found to be O. K. the actual defect could be noted."

Among the comments of those in favor of a score system were the following:

The chief engineer of the Division of Sanitary Engineering of the Department of Health, of a Middle West State, wrote, that while the system, as outlined, appeared to him to give too great a weight to the pollution hazards, he considered the report as of considerable help to his Department in developing a scoring system to apply to the water supplies of his State. He further stated that publication of such scores from time to time would, in his opinion, stimulate betterment of the supplies, although it was not his expectation that numerical ratings would be used in the publicity work.

One member of this Association wrote, "It seems to me that you have developed a workable system, which will, no doubt, be improved as experience with it is extended."

Discussion of Comments. The score system proposed by the Committee appears to be confused in some minds with an attempt to establish a standard similar to the bacteriological standard for drinking waters promulgated by the United States Treasury Department. Such is not the

case. The object of the score system is to list the many sanitary dangers, the several protective measures, and the desirable qualities of the water delivered. The assignment of numerical penalities and credits is for the purpose of indicating relative values in an approximately quantitative way. The Committee does not pretend that the values given are the best that can be selected, nor that they are exact, but it does believe that the values are relatively reasonable.

One criticism is to the effect that having scored a supply it is necessary to go back to its detailed description in order to find out the reason for the low score, should such be obtained. To the Committee, this seems an advantage rather than a disadvantage. If a low score involves return to a study of the supply for the purpose of determining the reason for the low score, the score system has served a distinctly useful service by bringing again to the attention of the individual studying the supply, some hazard or some failure to utilize protective measures to the best advantage. Furthermore, in attempting to score supplies, attention is frequently drawn to the lack of essential data without which a true opinion of the sanitary quality of the supply cannot be obtained.

It does not seem wise to use the numerical scores obtained from scoring water supplies for publicly comparing different water supplies. Where the supplies are scored by health departments, the results may well be used in pointing out to officials in charge of water supplies the necessity for improvements thereto and the significance of such improvements as measured by the score system. The score system also permits the waterworks superintendent to prepare his own balance sheet of sanitary assets and liabilities.

One criticism, to the effect that a municipality or water company should not be penalized because it had to take its supply from a polluted source, is beside the point. The supply is just as dangerous whether it is obtained through choice or through necessity.

The suggestions as to modification in the different values assigned were comparatively few. As a result of some of these suggestions and of further study, the Committee has revised somewhat the score system as outlined in its report of 1926 and submits herewith the revised system as Appendix I. The scores of some thirty-eight supplies, as worked out by the Committee, using the revised system, are given in Appendix II.

Factors Involved. In presenting the revised system of scoring, the Committee wishes to discuss briefly the factors which have been taken into consideration in the preparation of the score system.

It is self-evident that wherever there is resident population upon a watershed, there is a pollution hazard varying in general in proportion to the density of population. It is also self-evident that the danger from the direct discharge of sewage is much more than from the pollution which reaches watercourses indirectly. With a sewered population and the diversion of the sewage from the watershed, the hazard is materially less in some

cases and in others materially greater than with an unsewered population. It has seemed reasonable, therefore, to deal with population sewered off the watershed as though it were contributing indirect pollution.

It is true that the location of population upon a drainage area with respect to proximity to watercourses and water-supply intakes, is a factor which affects to some extent the relative pollution hazard. In the case of large rivers and the Great Lakes, this variation in hazard may be taken care of by zoning the drainage areas. In the case of the smaller drainage areas, the practical difficulty involved in differentiating between remote and near sources of pollution renders the attempt inadvisable.

Many drainage areas, otherwise practically uninhabited, may contain lumber camps or may be used for hunting, fishing, and other recreational purposes incidental to which there may arise real sanitary dangers. This is particularly true where the watershed is located near large centers of population as is the case with watersheds in eastern Massachusetts. The automobile brings a large transient population to remote watersheds. Accessible watersheds, free from permanent pollution, should be penalized. Although such practices usually occur whenever there is resident population, and approximately in proportion to the density of that population, the Committee feels that for watersheds having populations over one hundred per square mile, no additional penalty need be applied, on the ground that the penalty for population hazard is adequate to cover such items. The same reasoning has been applied to pollution of animal origin and to highways and railroads.

Industrial wastes have a variable effect upon the quality of water supplies according to the kind of wastes and the degree of dilution afforded. For example, a very small quantity of phenol wastes will have a marked effect upon the quality of a chlorinated water, whereas relatively large volumes of other wastes will have small effect. The Committee recognizes the fact that it is very difficult to fix a detailed gradation of penalties for industrial wastes, and suggests a maximum penalty leaving to the judgment of the individual scoring the supply, the penalty to adopt in any one case.

In the case of leaky intakes, suction mains, or gravity mains which pass through sewage-polluted waters, the penalty should be applied in those cases only where the intake is located in relatively unpolluted water. If the intake is in polluted water, there may be little or no difference in the quality of the water coming through the leaks and that through the intake.

Fishing, boating, ice-cutting, bathing, and other trespassing on reservoirs are well-recognized hazards. It is difficult to trace epidemics of water-borne diseases to such practices, but nevertheless it is evident that danger does exist, and a few instances are on record where the evidence pointed to their culpability in the causation of epidemics. Fishing, boating, and ice-cutting constitute less serious sanitary hazards than bathing, and the penalties have been selected accordingly.

The accessibility of storage and distribution reservoirs is a hazard frequently found, and one to which too little attention is paid. Open reservoirs in the center of well-built-up areas are subject to pollution, either willful or accidental. Suicides have no qualms with the respect to use of public water-supply reservoirs. Unskillful automobilists have been known to take involuntary plunges into such reservoirs. There is less hazard in fenced reservoirs, but covers are essential if complete protection is to be provided.

Double-storage tanks, one part for safe and the other for unsafe water, and leaky raw-water conduits passing through clear-water basins, are hazards of relatively infrequent occurrence but of considerable importance when existing.

One hazard which occurs frequently, is that due to the cross-connection of polluted industrial or fire-supply systems with the public mains. Much discussion has centered upon this subject. No question is raised as to the very serious hazard involved when such cross-connections are made with single or no check valves. Considerable differences of opinion exist, however, as to the hazards involved when such connections are made through double check-valves of the Factory Mutual type installed in accessible manholes and regularly inspected and tested. It must be granted that the maximum safety results from complete separation, and that experience has demonstrated that little dependence can be placed upon single check-valves. Double check-valves, although less liable to leak, are not absolutely safe and inspections and tests are necessary. We have, therefore, fixed a lower penalty for double check-valve installations but have not given them a clean bill of health.

The existence of dual water-supply systems, one from a safe source and used under normal conditions and another from an unsafe source used only in emergencies, is another hazard the relative danger from which is difficult to estimate, due to the difference in frequency with which the polluted supplies will be called upon. In some cases the penalty proposed may be inadequate and in others too great.

The danger resulting from inadequate pressure and storage is indirect. With low pressure and insufficient storage, recourse to other and unsafe sources may be required. Under certain conditions, an inadequate source of supply may constitute a real health menace.

It is probable that there may be an occasional supply subject to some special and unusual hazard, and for this reason "miscellaneous hazard" has been included. Where an unlisted hazard occurs, it is incumbent upon the individual preparing the score to use his own judgment as to the relative danger involved with the hazard in question.

It must be granted that it is practically impossible today to secure in nature a water supply of pristine purity. Nearly all sources of supply are subject to some source or mode of pollution. Natural barriers are imper-

fect and erratic. To secure adequate protection, artificial barriers must be established and carefully controlled.

First in order of protective measures are those relating to the abolition or abatement of sources of pollution. The treatment of sewage and of industrial wastes is of value in the reduction of pollution in proportion to the degree of treatment afforded. The establishment of sanitary rules and regulations for the protection of watersheds, their enforcement, regular patrol, and sanitary inspections are all of distinct value. Credits for these measures go to offset penalties for pollutional hazards.

The ownership of the drainage area permits the department or corporation controlling the supply, to control pollution. If the entire watershed is not owned, the value of such ownership as does exist is roughly in proportion to the amount of land owned. Storage as a protective measure has long been recognized and in New England is the most frequently met-with and relied-upon protective measure. Most water-borne infectious bacteria die off in two weeks' time and their destruction in a month's time is almost certain. Storage, although it cannot be relied upon implicitly, due to the uncertainty with respect to the actual degree of retention secured and the practical impossibility of absolute control, is of considerable value. Increasing draft tends to reduce the value of storage somewhat.

Methods for water purification by artificial means are important considerations. The credits for such methods have been fixed in accordance with the Committee's estimate of their relative reliability. Where the final score would exceed 100, the total credit for protective measures is limited to a definite figure inasmuch as measures may be adopted for which the situation does not call. Accordingly an excess of purification factors deserves no credit.

Purification and other protective measures, although provided, do not always work out as planned, and accordingly provision has been made for reducing the credits for such devices when they are inadequate or improperly put into effect.

The final test of water supply is the quality of the product delivered. The consumer wishes a clear water of low color, without odor or taste. A soft but non-corrosive water is desirable and one free from iron and manganese. From the sanitary standpoint these physical and chemical qualities are of course relatively less important than the bacterial qualities, although they do have an indirect bearing upon the health of the community. It is a well-known fact that where the public water supply is distasteful to the consumers, many will resort to other sources of supply of doubtful sanitary quality.

In selecting the penalty for bacterial results, the Committee has considered, but not adopted as a criterion, the standard of the Treasury Department. Admirable as this standard may be for the purposes for which it was established, it did not seem wise to the Committee to utilize

it for the purposes of scoring, due to the rather sharp division between acceptable and unacceptable results.

The Great Lakes, the St. Lawrence River, and the connecting rivers between the Great Lakes require special consideration. It is manifest that on the large watersheds tributary to these bodies of water the remote populations have no effect upon the quality of the supply. Limiting distances have been selected, based upon the probable limit of travel of pollution. Insofar as protective measures and quality conditions are concerned, the same credits and penalties are provided as for the main group of surface supplies.

In the case of ground-water supplies, the proximity of population and of pollution have been taken into consideration. It is evident that the materials through which wells pass are of considerable importance, as is the depth of such materials, so that varying credits are allowed according to the material penetrated. Furthermore, the ground-water supplies have been divided into two groups according to depth of tight casing. It is evident that credits and penalties for purification methods and for quality conditions should be the same as for the other groups.

References to examples of outbreaks of water-borne disease resulting from the hazards listed in the score system are given in Appendix III. The list is much abbreviated but is given to show that the hazards penalized have brought about serious consequences.

Conclusion. The Committee wishes it to be distinctly understood that it is not setting up any fixed standard. Furthermore, the Committee clearly recognizes the limitations of any system for scoring the quality of water supplies. In applying any score system, judgment must be used.

The difficulty involved in the attempt to indicate the relative dangers of the many different sanitary hazards is appreciated, as are the objections to establishing any quantitative score system at all. Moreover, it is not possible to determine an exact valuation for protective measures. The score system is a crude tool, not a precise instrument. It is of value for administrative purposes and as an aid to judgment. Above all, it can be used to bring about the fundamental objective of this Association, — the betterment of water supplies.

Recommendation. The Committee recommends that the score system herein presented be adopted by the Association as a tentative working system, subject to revision from time to time as further experience is obtained.

Respectfully submitted,

E. SHERMAN CHASE, *Chairman*,
J. FREDERICK JACKSON,
ARTHUR D. WESTON,
Committee on a System of Sanitary Scoring of Water Supplies.

September 13, 1927.

APPENDIX I.

OUTLINE OF SCORE SYSTEM.

(Modified as of September, 1927.)

SURFACE SUPPLIES.

(Main Group.)

I. *Pollution Hazards:*

Score for no hazard 60

Hazards connected with Sources of Supply:

1. Population on watershed (p = population per sq. mile of watershed):* (See Fig. 1.)

a. Contributing indirect pollution and where sewage is diverted from watershed ..... $-2\sqrt{P}$

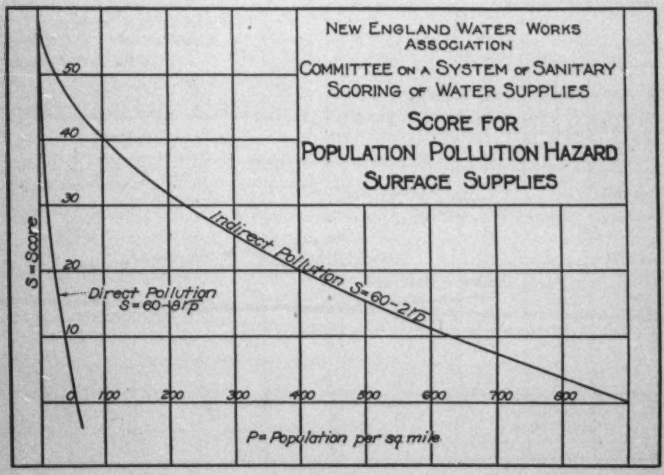

FIG. 1.

b. Contributing direct pollution (sewage) ..... $-8\sqrt{P}$

2. Highways and railroads (per linear mile per sq. mile of watershed)† ..... -1

3. Lumbering, labor camps, hunting, etc.:†

a. Lumbering, labor camps, etc. ..... -2

b. Hunting, picnicking, etc. ..... -1

4. Animal pollution:†

a. Direct ..... -2

b. Indirect ..... -1

5. Industrial wastes ..... -1 to -5

6. Leaky intake, suction main or gravity main from relatively unpolluted source passing through sewage-polluted water ..... -25 to -60

Hazards connected with Storage and Distribution of Supply:

*Zone large watersheds in 50-mile stretches by dividing by $\sqrt{d}$, where d = some multiple of 50 miles. (See Fig. 2.)

†2, 3 and 4. Applied only when population is less than 100 per sq. mile.

7. Fishing, boating, ice-cutting, bathing, etc., on distribution or small-storage reservoirs:
   a Fishing and boating ..... −2 to −25
   b. Ice-cutting:
      Ice house at reservoir ..... −2
      Ice house away from reservoirs ..... −1
   c. Bathing ..... −5 to −25
8. Accessible distribution reservoirs:
   a. Open and unprotected ..... −5
   b. Open but protected by locked fence, etc. ..... −2
9. Inadequate protection against polluted water leaking into pure-water reservoirs, e.g., double-storage tanks, one part for safe and other for unsafe water; leaky raw-water conduits passing through clear-water basins, etc. ..... −5 to −60

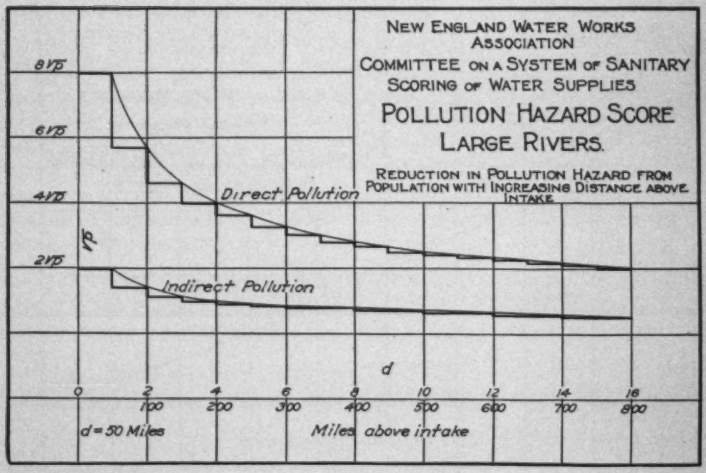

FIG. 2.

10. Cross-connections with polluted supplies:
   a. Single or no check valve should not be tolerated ..... −15 to −60
   b. Double-check, F. M. type, regularly inspected ..... −5
11. Dual water-supply systems, one from a safe source and the other, for emergency use, from a sewage-polluted source ..... −10 to −60
12. Inadequate pressure and storage ..... −10

Miscellaneous Hazards (unlisted). Penalize according to judgment.

II. *Protective Measures:*
Total score not to exceed 30

1. Sewage and industrial wastes treatment divide score for direct-pollution hazard and industrial wastes sewage according to extent of treatment, as follows:
   a. Sedimentation, divide by 2.
   b. Complete treatment without disinfection, divide by 3.
   c. Complete treatment with disinfection, divide by 4.

2. Proper sanitary regulation, patrol, and enforcement	4
3. Ownership of watershed, 100%	5
(For less than 100%, pro-rate according to area owned.)	
4. Storage (minimum):	
a. One month or more	10
b. Two weeks	5
5. Water Purification:	
a. Chlorination	10
b. Pressure mechanical filters:	
with coagulation basin	10
without coagulation basin	5
c. Gravity mechanical filters	15
d. Slow sand filters	15
e. Copper sulphate treatment, aëration, etc., for algæ	5
(For combinations of the above purification methods, add individual scores, total credited not to exceed 30.)*	
Penalties for Failure or Inadequacy of Protective Measures:	
1. Improper operation of sewage and industrial wastes treatment plants — allow no credit.	
2. Lax enforcement of sanitary regulations, improper or inadequate regulations, irregular patrol or none	−2 to −4
3. Short circuits in storage reservoirs	−5
4. Improper operation of purification plants (not to exceed credit for plant):	
a. Inadequate dosage of chlorine	−10
b. Intermittent operation of chlorination apparatus, absence of duplicate equipment, etc.	−5
c. No coagulant with mechanical filters	−10
d. Exhaustion of chemicals or chemicals of poor quality	−5
e. Filters in poor condition	−5
f. Combustible buildings housing essential equipment	−5
5. No or inadequate laboratory control of water quality	−5
6. Incompetent or untrained filter operator	−5
III. *Quality Conditions:* (Period covered not to exceed one year.)	
Total score not to exceed	30
Turbidity:†	
Clear	2
0 to 5 p.p.m.	1
Over 5 p.p.m.	0
Color:†	
Colorless	2
0 to 10 p.p.m.	1
Over 10 p.p.m.	0
Odor:†	
None	2
Penalty for bad odors up to	−5
Taste:†	
None	2
Penalty for bad taste up to	−5
Hardness:†	
Under 50 p.p.m.	1

*Except that excess credits may go to offset penalties upon protective measures and a maximum credit of 35 may be allowed with double filtration.

†Sum of credits for these qualities not to exceed 10.

Corrosiveness:*	
None	1
Iron and manganese:*	
Less than 0.5 p.p.m.	1
Penalty for excess of 1 p.p.m.	−3
Total bacterial counts on agar at 37° C. — 24 hrs.:*	
Less than 100 per c.c.	5
Over 100 per c.c.	0
B. coli type:	
Absent in 100% of 10 c.c. inoculations	20
(Present in part of 10 c.c. inoculations, pro-rate according to per cent. of samples positive.)	

NOTE: TOTAL SCORE NOT TO EXCEED 100.

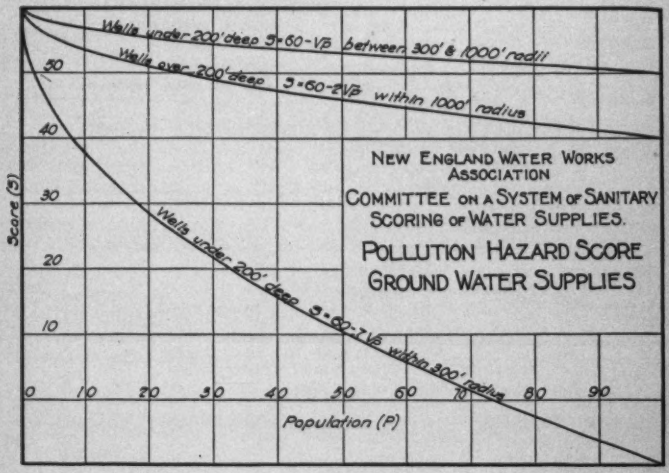

FIG. 3.

SURFACE SUPPLIES.

(Sub-group: Great Lakes, connecting rivers and St. Lawrence River.)

I. *Pollution Hazards:*	
Score for no hazard	60
Population within two weeks' maximum velocity time of flow above intake in case of river, or within 30 miles of intake in case of Great Lakes (p = population 1 000)	
a. Contributing indirect pollution	$-\frac{1}{2}\sqrt{P}$
b. Contributing direct pollution	$-2\sqrt{P}$
(Other pollution hazards score, where applicable, the same as for main group.)	
II. *Protective Measures:*	
Same as for main group.	
III. *Quality Conditions:*	
Same as for main group.	

*Sum of credits for these qualities not to exceed 10.

Ground Water Supplies.

(Main group: depth less than 200 ft.*)

I. *Pollution Hazards:*

Score for no hazard 60

1. Population (p = population): (See Fig. 3.)
   - *a.* Between radius of 300 ft. and 1 000 ft. ..... $-\sqrt{P}$
   - *b.* Within radius of 300 ft. ..... $-7\sqrt{P}$
2. Sewers, cesspools, etc., within 300 ft. ..... −10
3. Improperly protected top ..... −5
4. Leaky casings ..... −5
5. Connections with polluted surface water ..... −10 to −60
6. Flooding within 300 ft. by sewage-polluted surface water ..... −5
7. Distribution hazards:
   The same as for surface supplies.

II. *Protective Measures:*

Total score not to exceed 30

1. Depth and kind of strata penetrated:
   - Sand under 20 ft. in depth 5
   - Sand over 20 ft. in depth 15
   - Sand and gravel under 20 ft. in depth 3
   - Sand and gravel over 20 ft. in depth 10
   - Seamy rock and limestone 0
   - Impervious layer above water-bearing stratum 10
2. Purification methods:
   Credits and penalties the same as for surface supplies.

III. *Quality Conditions:*

The same as for surface supplies.

Ground Water Supplies.

(Sub-group: depth more than 200 ft.*)

I. *Pollution Hazards:*

Score for no hazard 60

1. Population (p = population):
   - *a.* Within a radius of 1 000 ft. ..... $-2\sqrt{P}$

   (Other pollution hazards the same as for main group.)

II. *Protective Measures:*

Total score not to exceed 30

1. Overlying soil:
   Same as for main group.
2. Purification methods:
   Credits and penalties the same as for surface supplies.

III. *Quality Condition:*

The same as for surface supplies.

---

*"Depth" means depth of tight casing.

APPENDIX II.

List of Scores of Some Thirty-eight Water Supplies.

Supply.	I. Pollution Hazards.	II. Protective Measures.	III. Quality.	Final Score.
Surface Supplies:				
1	41	16	30	87
2	46	16	26	88
3	28	15	30	73
4	34	30	27	91
5	26	11	30	67
6	58	10	30	98
7	38	21	27	86
8	27	21	28	76
9	40	22	27	89
10	27	11	27	65
11	−5	24	30	49
12	7	34	30	71
13	45	15	30	90
14	27	20	30	77
15	32	10	29	71
16	26	10	11	47
17	33	10	12	55
18	33	20	14	67
19	38	0	2	40
20	30	30	30	90
21	43	0	29	72
22	38	10	10	58
23	37	30	28	95
24	38	24	24	86
25	25	25	29	79
26	51	21	19	91
Great Lake Supplies:				
27	31	30	24	85
28	−20	25	30	35
Ground Water Supplies:				
29	−14	15	30	31
30	46	15	30	81
31	28	20	30	78
32	50	15	30	95
33	60	10	30	100
34	53	0	18	71
35	50	10	25	85
36	46	15	25	86
37	41	20	25	86
38	55	3	30	85

Note: The above scores were made by Committee according to score system presented with this report. The data used were largely contributed by engineers and superintendents.

APPENDIX III.

Outbreaks of Examples of Water-Borne Disease Resulting from Sanitary Hazards Listed in Score System.

(Partial List.)

1. *Pollution Hazards.*

Hazards Due to Population on Watershed:
- Chicago, Ill.: Eng. News-Rec., vol. 92, p. 116, Jan. 17, 1924.
- Cochrane, Ont.: Eng. News-Rec., vol. 90, p. 714, Apr. 19, 1923.
- Maidstone, Eng.: Jour. A.W.W.A., 1910, p. 299.
- Westfield, N. Y.: N. Y. State Dept. Health, 1915, vol. 2, p. 691.

Leakage of Sewage into Ground Water:
- Walden, N. Y.: N. Y. State Dept. Health, 1913, p. 761.

Poorly Protected Ground-Water Supply:
- Akron, N. Y.
- Greenville, Tenn.: Jour. A.W.W.A., 1921, p. 132.
- Santa Ana, Cal.: Eng. News-Rec., vol. 92, p. 409, March 6, 1924.

Lumbering, Labor Camps, etc.:
- Ithaca, N. Y.: Jour. N.E.W.W.A., 1904.
- Peekskill, N. Y.: N. Y. State Dept. Health, 1908, vol. 1, p. 493.
- Raybrook, N. Y.: N. Y. State Dept. Health, 1917, vol. 2, p. 493.

Leaky Well-Casings, etc.:
- Bad Axe, Mich.: Eng. News-Rec., vol. 91, p. 138, July 26, 1923.
- Fond du Lac, Wis.: "Public Water-Supplies," by Turneaure and Russell, p. 171.
- Salem, O.: Jour. N.E.W.W.A., 1921, p. 335.

Connections with Polluted Surface Water:
- Mankato, Minn.: Jour. N.E.W.W.A., 1920, p. 44.

Flooding of Ground-Water Supplies by Polluted Surface Water:
- Corning, N. Y.: N. Y. State Dept. Health, 1912, p. 777.
- Old Salem, Chautauqua, O.: Jour. A.W.W.A., 1916, p. 874.

Hazards Due to Location or Condition of Intake:
- Clayton, N. Y.: N. Y. State Dept. Health, 1900, vol. 2, p. 472.
- Ottawa, Canada: Jour. A.W.W.A., 1911, p. 151.
- Tonawanda, N. Y.: N. Y. State Dept. Health, 1919, vol. 2, p. 331.

Fishing, Ice-Cutting, etc., on Reservoirs:
- Hillsdale, Mich.: Jour. Am. Med. Assoc., vol. 77, no. 22, Nov. 26, 1921.
- Peabody, Mass.: Jour. N.E.W.W.A., 1920, p. 193.
- Sherburne, N. Y.: N. Y. State Dept. Health, 1908, vol. 1, p. 513.

Accessible Distribution Reservoirs:
- Hudson Falls, N. Y.: N. Y. State Dept. Health, 1914, vol. 2, p. 355.

Cross-Connections with Polluted Supplies:
- Bloomington, Ill.: Jour. A.W.W.A., 1920, p. 560.
- Everett, Wash.: Public Health Reports, March 28, 1924.
- Fort Wayne, Ind.: Eng. News-Rec., vol. 92, p. 348, Feb. 28, 1924.
- Rockaway, N. J.: Pub. Health News (M.J.), June, 1923.
- Sterling, Ill.: Eng. News-Rec., vol. 94, p. 526, March 26, 1925.

Emergency Supply from Polluted Source:
- Herkimer, N. Y.: N. Y. State Dept. Health, 1918, vol. 2, p. 242.
- Watervliet, N. Y.: N. Y. State Dept. Health, 1917, vol. 2, p. 561.

Inadequate Pressure:
- South Pasadena, Cal.: Eng. News-Rec., vol. 92, p. 1018, June 12, 1924.

II. *Failure or Inadequacy of Protective Measures.*

Short Circuits in Storage Reservoirs:

Auburn, N. Y.: Jour. A.W.W.A., 1914, p. 688, 1920, p. 42.

Seneca Falls, N. Y.: N. Y. State Dept. Health, 1918, vol. 2, p. 387; 1920, vol. 2, p. 312.

Improper Operation of Filters:

Geneva, N. Y.: N. Y. State Dept. Health, 1917, vol. 2, p. 333.

Moline, Ill.: Jour. A.W.W.A., 1919, p. 230.

Weston, W. Va.: Reducing the Typhoid Toll in West Virginia, E. S. Tisdale, p. 16.

Flooding of Filters:

Albany, N. Y.: N. Y. State Dept. Health, 1913, p. 733.

Inadequate Dosage of Chlorine:

Lackawanna, N. Y.: Health News, N. Y. State Dept. Health, Jan. 18, 1926, p. 12.

Intermittent Operation of Chlorination Apparatus, Absence of Duplicate Equipment, etc.:

Grafton, W. Va.: Public Health Reports, vol. 42, no. 18, May 6, 1927, pp. 1217-1219.

Pittsburg, Cal.: Eng. News-Rec., vol. 85, p. 1288, Dec. 30, 1920.

Exhaustion of Chemicals or Chemicals of Poor Quality:

Green Island, N. Y.: N. Y. State Dept Health, 1918, vol. 2, p. 213.

Wheeling, W. Va.: W. Va. State Dept. Health Bulletin, July, 1922.

Filters in Poor Condition:

Charleston, W. Va.: Reducing the Typhoid Toll in West Virginia, E. S. Tisdale, p. 11.

Inadequate Laboratory Control of Water Quality:

Mt. Vernon, N. Y.: N. Y. State Dept. Health, 1920, vol. 2, p. 267.

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LEWIS D. THORPE
Civil and Sanitary Engineer
Water Works, Sewerage and Sewage Disposal
Supervision of Construction and Operation
6 Beacon Street
BOSTON, MASS.

THE PITOMETER COMPANY
ENGINEERS
Water Waste Surveys
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Water Distribution Studies
Penstock Gaugings
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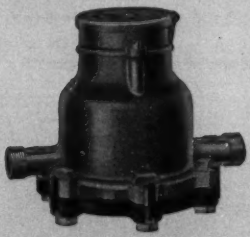
Clean Corroded Pipe and Water Mains.
Clean pipe lines deliver more water and give better fire protection at less cost than do corroded mains.
Let us help you with your problems.
GENERAL PIPE CLEANING COMPANY
735 Commercial Trust Bldg. Philadelphia, Pa.

CONTRACTORS

G. FERULLO COMPANY
General Contractors
Specializing in Water Works
31 NORTH SQUARE
BOSTON, MASS.
Telephone, Richmond 1200

THE Disc Piston of a Hersey Water Meter is perfectly balanced. That helps to explain the amazing registration accuracy of this meter over long periods of years. Practically no friction—no wear—no reason for frequent resetting.



Hersey makes the only water meter which is entirely protected against corrosion by the expensive dipped-tinned process.

Hersey Manufacturing Company, South Boston, Mass.

HERSEY
WATER METERS

NEW YORK, N. Y. ..... 290 Broadway
PORTLAND, ORE. ..... 473 Hoyt St.
PHILADELPHIA, PA. ..... 314 Commercial Trust Bldg.
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Main Office and Works:
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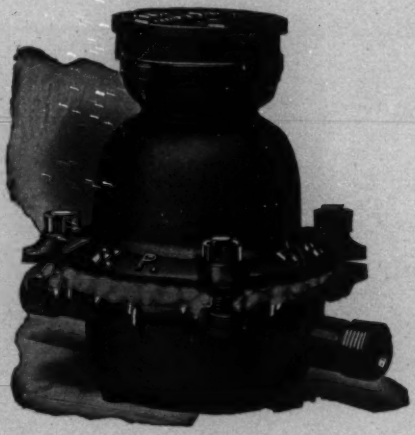


FROZEN!—but not damaged

Here is an actual photograph of a LAMBERT Frost-proof Meter which has been frozen to an extent that would put the ordinary meter completely out of commission.

This is made possible by a patented, non-corrosive yielding bolt device which allows the upper and lower casing, disc chamber and gear train to part without damaging the meter in any way. Five minutes' labor the only repair cost.

The expense and annoyance from frozen water meters can be eliminated for all time through the installation of the LAMBERT Frost-proof.

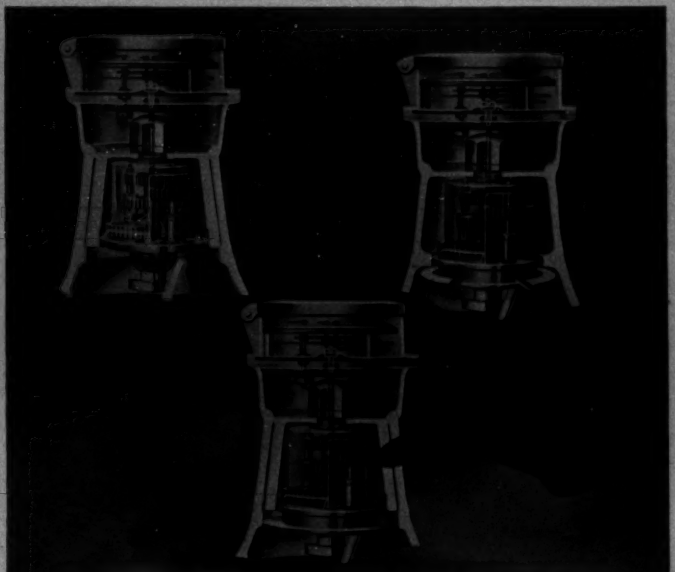
It has been proved that the LAMBERT is the easiest water meter to take apart and put together again as well as the simplest, most reliable and accurate.

If you are interested in other types of meters, we make one for every requirement.

THOMSON METER CORPORATION

SALES OFFICE: 50 EAST 42nd STREET, NEW YORK CITY, N. Y.

LAMBERT FROST-PROOF METERS



The First Successful Oil-Enclosed Gear Train—was Trident

No need to repeat here what this pioneering Trident development means in *sustained sensitivity* and consistently uniform revenue through reducing wear and preventing corrosion of the gear train. Illustration shows the interchangeability of Gear Train in (first) old casing; (second) old type gear train in new casing; and (third) modern type gear train in new casing (lower, center picture).

Of Trident and Lambert Meters, over 4,500,000 have been made and sold the world over.

The eight outstanding pioneering developments in water meter design were all TRIDENT. Write for catalog giving full particulars.

"The Cash Registers of the Water Works Field"

NEPTUNE METER COMPANY
THOMSON METER CORPORATION
50 EAST 42ND STREET NEW YORK CITY
FACTORY LONG ISLAND CITY, N.Y.
PIONEERS IN METER PROGRESS

ANNOUNCEMENT

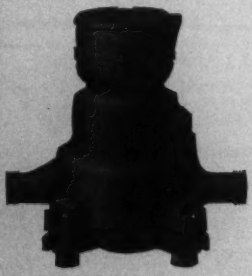
Pittsburgh Water Meters will hereafter be manufactured and sold by the Pittsburgh Equitable Meter Company.

The Pittsburgh Equitable Meter Company will have very much larger facilities and, therefore, the trade is assured that the same products will be available with no change, except in the benefits accruing from the increase in both the organization and plant facilities.

Water Meter stocks will be carried in a number of new branches and additional offices will soon be announced, which will enable us to keep in closer touch with the trade.

PITTSBURGH EQUITABLE METER CO.

WATER METERS FOR EVERY PURPOSE
DOMESTIC AND INDUSTRIAL

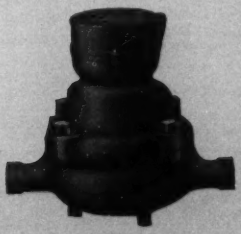


ARCTIC

A frost-bottom meter, especially designed for cold sections of the country.

TROPIC

An all bronze Water Meter, with connection spuds attached to the lower case. Particularly designed for warm sections of the country.

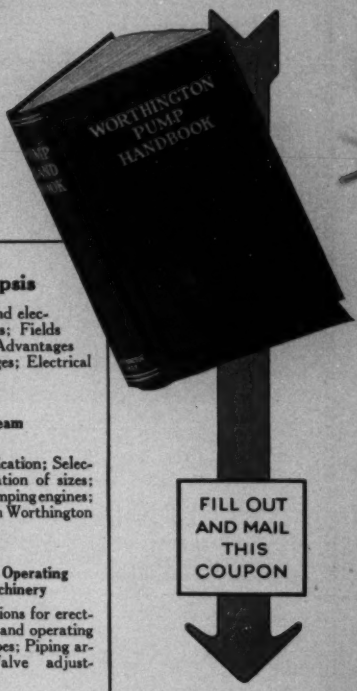


PITTSBURGH EQUITABLE METER CO.
PITTSBURGH, PENNA.

WORTHINGTON

A complete up-to-date pump treatise

550 pages, size 6 x 9
298 illustrations, cloth bound



Section Headings and Synopsis

General Theory and Units

Definitions; Properties of liquids; Principles of mechanics, hydraulics and thermodynamics with special reference to pumping problems; Pump selection and operation; Factors influencing pump selection; Table of pump fittings for various liquids.

Centrifugal Pumps

Types; Principle of operation; Design problems; Characteristics; Types for low service, general service, high pressures; boiler-feeding and special services; Sizes and data on Worthington types.

Power Pumps

Basic types; Advantages and disadvantages; Applications; Cost of operation; Mechanical details; Sizes and data on Worthington types.

Deep-well Pumps

Description of rotating types; *Axiflo* and *Coniflo* Pumps; Range of capacities; Characteristic curves; Fields of application; Reciprocating types; *Glendora.*

Power for Pump Drives

Oil-engine, gasoline-engine, kerosene-engine, waterwheel, steam-turbine and electric-motor drives; Fields of application; Advantages and disadvantages; Electrical data.

Direct-acting Steam Pumps

Types and application; Selection and calculation of sizes; Water works pumping engines; Sizes and data on Worthington types.

Installing and Operating Pumping Machinery

General instructions for erecting, starting up and operating pumps of all types; Piping arrangements; Valve adjustments.

Pumping in the Petroleum Industry

Analysis of requirements; Properties of oil; Flow laws; Well pumping; Pipe-line pumping; Loading and unloading; Refining; Data on Worthington pumps for all of these services.

Tabular Section

Tables of weights and measures, U. S. and Metric; Conversion and equivalent tables; American pipe standards; Fire-stream nozzle, discharge and pressure tables.

39-6071-8-82

WORTHINGTON PUMP and MACHINERY CORPORATION
115 *Broadway, New York City*
Gentlemen:

Please send me circular No. 6071-3 describing your Pump Hand Book, together with specifications for receiving free copy. I assume no obligations.

Name .....

Address .....

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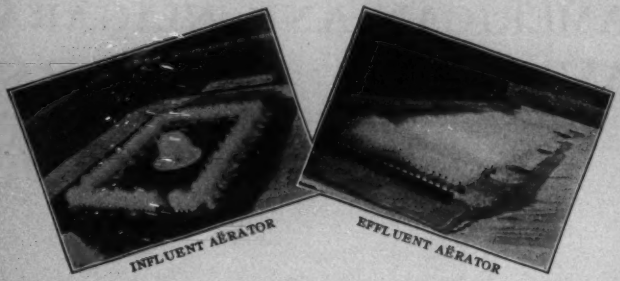


Views at new Providence Water Works Scituate, R. I.

At Providence

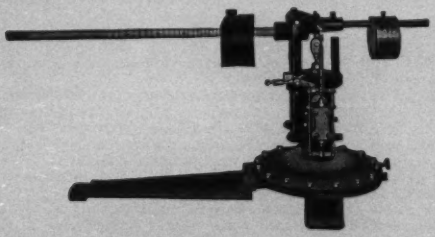
Hazen & Whipple Consulting Engineers, New York, N. Y.

the expenditure of twenty million of dollars and eight years of construction have resulted in providing the city of Providence with an abundant supply of pure clear water.

The Filter Effluent Aërators, a novel idea devised by the Consulting Engineers and developed by Builders Iron Foundry, is of particular interest. The head of water on the filter is used to produce secondary aëration. Constant flow through the filters is maintained by special Venturi-controlled mushroom valves which open gradually as the loss of head increases.

Special Venturi Meters measure the total water entering and leaving the plant; Builders Loss of Head and Rate of Flow Gages guide the operation of the filters.

Write for descriptive bulletins.



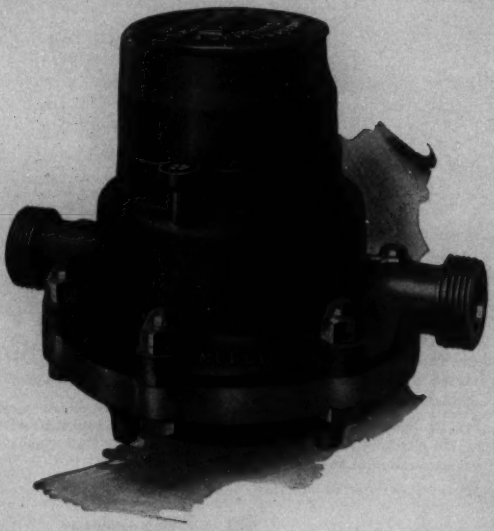
CONTROLLER PILOT VALVE UNIT

BUILDERS IRON FOUNDRY

"Builders of the Venturi for 36 Years"

Providence VENTURI Rhode Island

AMERICAN AND NIAGARA WATER METERS



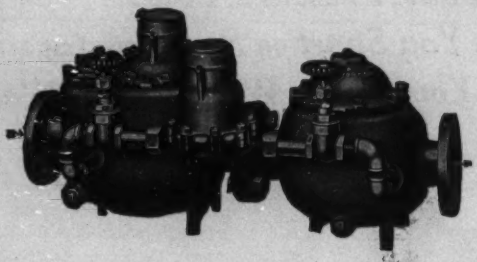
American and Niagara meters are made in solid casing types and frost bottom types. The illustration above shows a $^{5}/_{8}$" x $^{3}/_{4}$" meter of the frost bottom type. Those meters having bronze outside casings are known as Americans and those having galvanized cast-iron outside casings are Niagaras. The works in all the different casings are of one best model and interchangeable. The registers may be either round reading or straight reading and may indicate cubic feet, U. S. gallons, imperial gallons or litres. All Niagara and American meters are tested and adjusted according to the requirements of the Standard Specifications for water meters adopted by the New England Water Works Association and the American Water Works Association.

Write for large catalog and prices.

BUFFALO METER CO.

ESTABLISHED 1892

2896 Main Street **BUFFALO, N. Y.**



The New Nilo

The new improved **Nilo Compound Meter** now comes equipped with a bronze body. This is a valuable addition to meter service for it eliminates the danger of corrosion and filling up due to the collecting of corrosive matter. Bronze being stronger than iron the gross weight of the meter is less, making it easier to transport, handle and install.

It also has two gate valves which allow the removal of the by-pass meter for cleaning or repairing without shutting off the line.

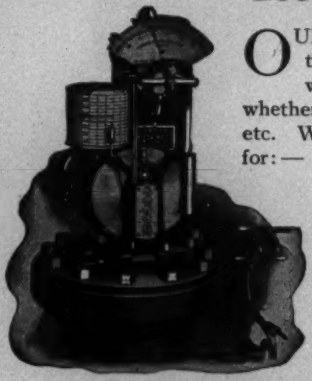
The controlling valve mechanism of the new **Nilo Compound Meter** is self contained and easily detached from the main body casings.

These three improvements make the **Nilo,** a long standing favorite, the unrivaled leader in its field.

An old-line New England Product
that has kept abreast of the times.

UNION WATER METER CO.
Incorporated 1868
WORCESTER, MASSACHUSETTS

Is Your Pressure Low?
Are You Short on Pumping Capacity?
Do You Know Where Your Water Goes?



OUR Engineering Department will tell you how to determine your water distribution, how to find out whether or not new mains are required, etc. We can supply you with the means for: —

1. Checking up pump performance and determining slippage due to leaky plungers, defective valves, short stroking or other causes,
2. Measuring delivery of centrifugal pumps and figuring whether or not the station is up to efficiency,
3. Distributing proportionately the cost of water supplied to several districts,
4. Checking up the performance of filter beds,
5. Detecting waste or pipe leakage,
6. Recording daily amounts of sewage handled and planning future extensions, etc., etc.

THE SIMPLEX METER

VENTURI, PITOT TUBE OR ORIFICE TYPES

THE importance of exact measurements by means of a Simplex Meter cannot be over emphasized. Mr. Jeffries, Chairman of the West Chester, Pa. Water Works Committee, was able, by checking the performance of his pumping engine with a Simplex Meter, to discover that due to the imperfection and wear in the valves the slippage amounted to 300,000 gallons of water per day. This represented a daily loss of $30.00, or in other words a daily saving of $30.00, or $900.00 per month, when the valves were put in order. The Simplex Meter thus paid for itself in a month's time.

Frequent repeat orders from satisfied customers who formerly used other meters are the best evidence of merit of the Simplex Meter.

We have had many years' experience in solving water flow problems involving all sorts of conditions, and we are at all times prepared to submit general layouts involving cost and capacity, and to make explicit and complete recommendations. Write for Bulletin N26.

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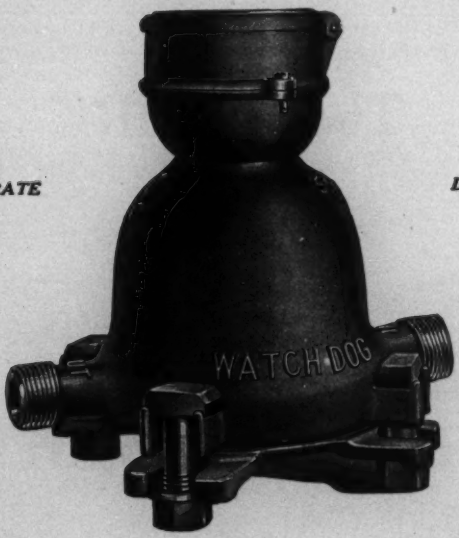
Manufacturers of Meters for Water, Sewage, and Other Liquids, Rate Controllers, Automatic Air Valves, Regulating Valves, and Hydraulic Apparatus of Special Design.

6757 UPLAND STREET PHILADELPHIA, PA.

"WATCH DOG" WATER METERS

ACCURATE *DURABLE*



DISC, CURRENT AND COMPOUND TYPES

Inquiries Solicited

GAMON METER COMPANY

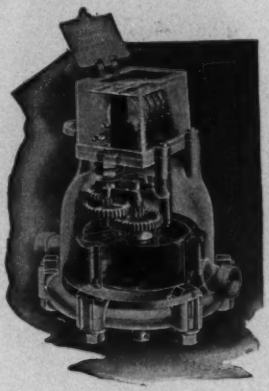
NEWARK NEW JERSEY

METERS

Water Departments wishing to make the most out of their supply, to earn the highest possible revenue, and to satisfy their customers, are invited to investigate

The EMPIRE

OSCILLATING PISTON METER



Sizes from 5/8″ to 6″

Accuracy, lasting qualities, and economy of upkeep are the three essentials of satisfactory meters. The EMPIRE offers some remarkable records on these three points. Ask us.

Fully descriptive EMPIRE circular gladly sent on request.

NATIONAL METER COMPANY

299 Broadway, New York

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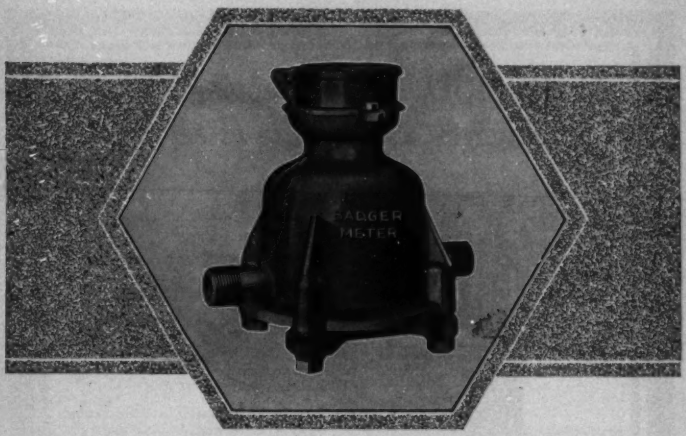
Atlanta **San Francisco** **Los Angeles**

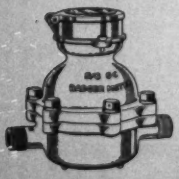


Day In and Day Out!

Hot weather, cold weather, under any conditions, a good, lasting meter — this Badger "A". Sturdy, durable. Built to a high standard.

Trouble proof lines are the aim of the modern water works.

Badger Model "A's" are a big step in that direction. They combine long years of service with accurate registration at lowest maintenance cost. And this because of simple design and heavy construction. Let us show you what Badger Meters will do for you.



Badger Meter Manufacturing Co.
Milwaukee, Wis.

Branch Offices:

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NEW YORK CITY 52 Vanderbilt Ave.
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BADGER *Water* METERS

Let the MUELLER "B" Tapping Machine bring you a long term of service

Measured by years —not months!

Why continue to worry about those worn-out, old tapping machines? Don't use them until they break down completely, leaving you stranded in the middle of an important job!

Replace them with new machines now and enjoy the difference. See how much easier and quicker you can do a good job with good tools. Crew time is wasted when the men are equipped with the wrong kind of machinery. Mueller "B" Tapping Machines save the time of installation crews and cut down payroll expense.

Mueller Tapping Machines are built for long service and hard wear. Their life of efficient operation is measured by years—not months. Hundreds of their famous tools are in use everywhere, giving satisfactory service in all cases.

You, who must watch the payroll; who must account for installation, will find it to your advantage to investigate the Mueller "B" Tapping Machine. In it you are sure to find the solution to your pipe tapping problems.

We will be glad to send full particulars about this and other products from the famous, 70-year-old, Mueller line. Write for complete information, catalog, data, etc., TODAY!

MUELLER CO. *Established 1857* **Decatur, Illinois**

Branches: New York, Dallas, San Francisco, Los Angeles
Canadian Factory: MUELLER, Limited, Sarnia

MUELLER

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ATTENTION
WATER WORKS
OF NEW ENGLAND

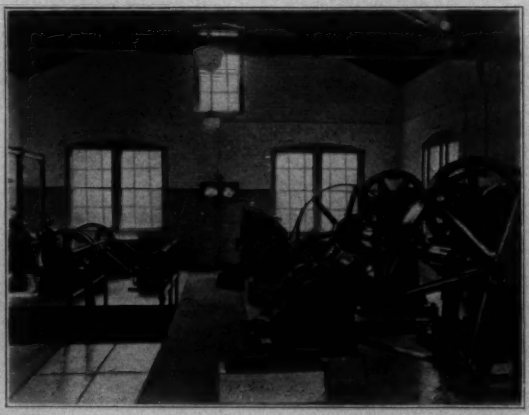
A few reasons why we solicit your inquiries on Water-Works Pumping Equipment:

First. — We make a specialty of furnishing Complete Water-Works Pumping Units of all types.

Second. — Total responsibility of installation is assumed by us.

Third. — We relieve the purchaser of every detail and turn the complete unit over to him under actual operation and with guarantee.

Fourth. — Every unit installed to date has exceeded its guarantee and has been completely accepted.



Remodeled Pumping Station at Bridgewater, Mass., completely installed by F. A. Mazzur Co., Inc. Barbour & Dixon, Eng'r's.

F. A. Mazzur Co., Inc.

141 MILK STREET, BOSTON

STARKWEATHER & BROADHURST, Inc.

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for

COMPLETE PUMPING PLANTS

Water or Sewage

"One Contract and Responsibility"

with

"Service Before Profit"

HORIZONTAL AND VERTICAL DESIGNS
MOTOR, STEAM TURBINE OR
DIESEL OIL ENGINE DRIVES
MOTOR AND GASOLINE ENGINE COMBINATIONS

Some Recent New England Installations

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Four Motor Units.

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Three Motor Units.

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Eight Motor Units.

Town of Warren, R. I.
One Motor Unit.

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One Turbine Unit.

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Five Motor Units.

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Three Motor Units.

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Three Motor Units.

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Two Motor Units.

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One Motor Unit.

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Four Motor Units.

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Two Motor Units.

Town of Amesbury.
Two Motor Units.

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Pumping Plant Contractors

CENTRIFUGAL, POWER, STEAM PUMPS

STEAM TURBINES
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Power Plant Equipment
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For new pumping equipment guaranteed by people who will make good, phone, wire or write the above.
Sales Agents for UNION STEAM PUMP CO.

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Water Tanks
Gas Holders
and all other metal surfaces need the protection of
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JOSEPH DIXON CRUCIBLE CO. Jersey City, N. J.

WE announce our appointment as Sales Representatives of DAYTON-DOWD COMPANY, of Quincy, Ill., Manufacturers of Centrifugal Pumping Machinery. After exhaustive investigation, we present this line of equipment to the Trade in New England as being of the highest grade and thoroughly modern in design and manufacture.

We are prepared to furnish DAYTON-DOWD pumps in all sizes and for all classes of service, in steam, motor, gasoline and belt drive types, and solicit your inquiries, assuring you of our best efforts in your sales and service requirements, and of our appreciation of your continued confidence and patronage.

POWER EQUIPMENT CO.

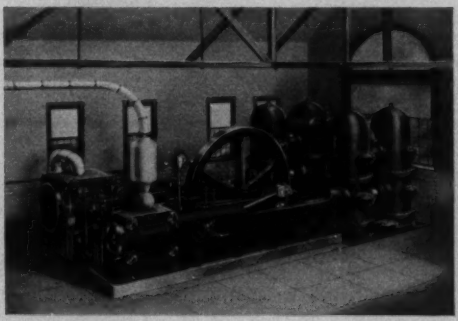
131 State Street, Boston, Mass.

MURRAY IRON WORKS CO.

(INCORPORATED 1870)

BURLINGTON, IOWA, U. S. A.

Builders of High Duty Pumping Engines



Murray High Duty Crank and Fly Wheel Pumping Engine, Opposed Type

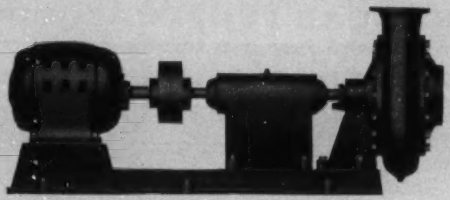
Engineers, Iron Founders, Boiler Makers

Corliss and Una-Flow Engines

Water-Tube, Fire-Tube and Internal-Furnace Boilers

Builders of Complete Power Plants

PLEASE SEND US YOUR SPECIFICATIONS AND CALLS FOR BIDS



Fairbanks-Morse Horizontal Trash Pump direct-connected to Fairbanks-Morse Ball-Bearing Motor

Now a great advance in sewage pumping

For the first time a pump has been designed that will handle fluids containing the fibrous and stringy matter found in sewage — without clogging, without preliminary screening, and without the excessive power consumption that characterizes the less satisfactory open impeller type of pump.

The secret of this pump's success lies in the design of the simple two-blade impeller. The blades of the impeller have well-rounded entering ends and are well filleted with the shrouds or sides. Thus a rag or other trash does not find sharp projections on which to catch and cause clogging. Since the impeller is the enclosed type, foreign matter, in passing through, does not come into contact with stationary side plates, but is promptly discharged through one of the large ports into the pump case. In this way power is conserved and efficiency increased.

This pump was designed by Mr. A. B. Wood who has been serving the city of New Orleans and other municipalities in the capacity of consulting engineer. It was originated by Mr. Wood to cope with the very unusual sewage problems found in New Orleans and met with immediate success.

Fairbanks-Morse Trash Pumps are made in two types, horizontal and vertical. They are ruggedly built to cope with severe service and at the same time they possess such refinements as ball bearings, smoothed fluid passages, and other marks of quality construction.

Ask for bulletins giving complete details.

FAIRBANKS, MORSE & CO., Chicago

28 branches in principal cities at your service.

FAIRBANKS-MORSE

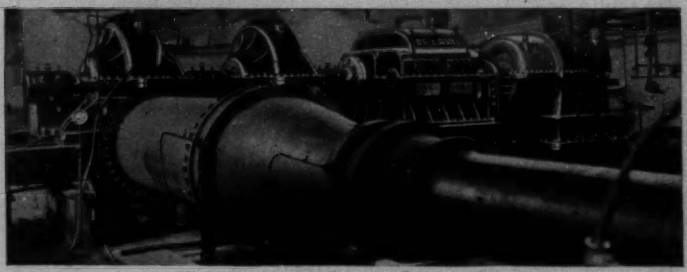
PUMPS · DIESEL ENGINES · MOTORS

DE LAVAL

CENTRIFUGAL PUMPING EQUIPMENT

is the accepted standard for

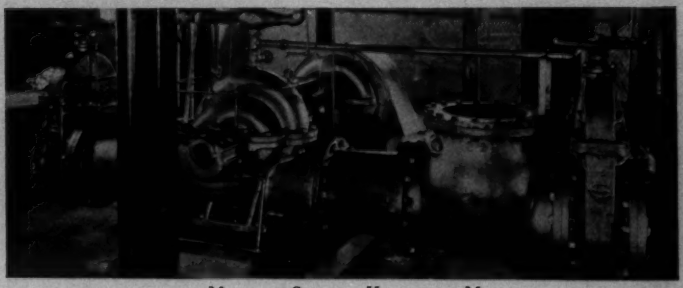
MUNICIPAL WATER WORKS



WESTERN AVENUE PUMPING STATION, CHICAGO.

The largest Municipal steam turbine driven centrifugal pumping unit in the world delivering 75 million gallons per day against 150 feet head.
City of Chicago has fourteen large DE LAVAL pumping units.

TYPICAL NEW ENGLAND INSTALLATION



MILLVALE STATION, HAVERHILL, MASS.

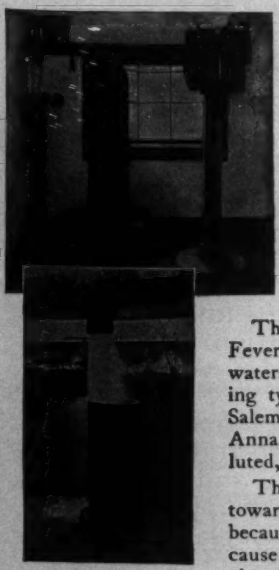
New 7 million DE LAVAL motor-driven pump including the furnishing and erection of transformers and switchboard equipment. On test after installation this pump delivered water at rate of 7,800,000 gallons per day. Another DE LAVAL unit is on order for Kenoza Station, Haverhill.

Recent DE LAVAL municipal water works contracts include New England installations at Canton, Mass., and Millis, Mass.

Ask for De Laval Publication.

TURBINE EQUIPMENT CO. of NEW ENGLAND
CHAMBER OF COMMERCE BUILDING
80 Federal St., Boston
NEW ENGLAND REPRESENTATIVE FOR
DE LAVAL STEAM TURBINE COMPANY
Trenton, N. J.

All Well Waters —Should Be Chlorinated



The Elizabethtown Water Company, Elizabeth, New Jersey uses the new W & T Chlorinator, type M S P, to sterilize every drop of well water.

PUBLIC HEALTH ENGINEERS are rapidly dissipating the old-fashioned but popular idea that well waters are pure and safe to drink just because they are well waters and come from under-ground sources.

They know that well waters are liable to pollution—that a fissure in the rock or a break in the well casing often permits disease ladened contamination to enter the supposedly pure water—particularly in times of flood.

They know that hundreds of Typhoid Fever Epidemics have been caused by well waters.—They know that the three outstanding typhoid epidemics in recent history—Salem, Ohio — Lansing, Michigan — Santa Anna, California—were all caused by polluted, *unchlorinated* well water.

That is why there is a marked tendency toward the chlorination of all well waters—because a properly chlorinated water cannot cause disease—because chlorination will not change the physical or chemical characteristics of the water in any way — because chlorination costing but one cent per capita per year is the cheapest public health insurance.

"The Only Safe Water is a Sterilized Water"

WALLACE & TIERNAN

COMPANY, INCORPORATED

Manufacturers of Chlorine Control Apparatus

NEWARK, NEW JERSEY

NEW YORK CHICAGO KNOXVILLE SAN FRANCISCO MINNEAPOLIS PITTSBURGH DALLAS
KANSAS CITY LOS ANGELES SEATTLE ST. LOUIS BUFFALO HARRISBURGH INDIANAPOLIS
DETROIT WALLACE & TIERNAN, LTD., TORONTO, CANADA
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Ha

Founded 1853 Incorporated 1863

MERRIMAC CHEMICAL COMPANY 1863

FILTER ALUM

Aluminum Sulphate

A basic, uniform product which has been used successfully by the leading water filtration plants in New England for many years.

Our location and shipping facilities place us in a position to offer insurpassable service and make us the logical source of supply for all filter plants in New England.

The aid and advice of our technical staff has often proved of great value to our customers. It is always at their service.

MERRIMAC CHEMICAL CO.

148 STATE ST., BOSTON, MASS.

Works:

EVERETT, MASS. WOBURN, MASS.

PRECALKED JOINT PIPE

Can be laid three times as fast as ordinary pipe, for half the labor. B. & S. type. Sand cast. Precalked Fittings also.

McWane Cast Iron Pipe Company

Eastern Office
819 Bankers Trust Bldg.
Philadelphia

New England Representatives:

FRED A. HOUDLETTE & SON
40 Central Street, Boston
Eastern Mass., Me., N. H.

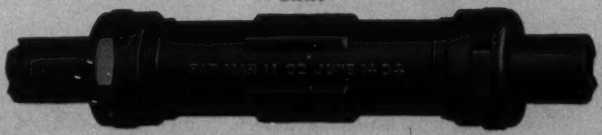
BUILDERS IRON FOUNDRY
Providence, R. I.
R. I., Conn., Vt., Western Mass

GRIP PIPE FITTINGS

Connect without threading

As an Emergency Pipe Clamp

Before



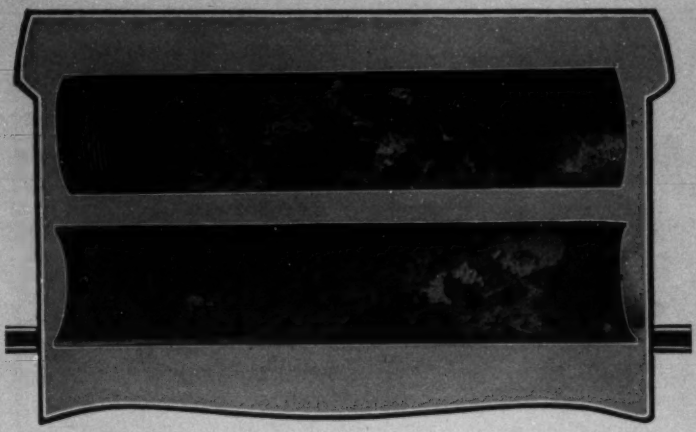
After

Makes Possible an Immediate Repair. Saves Both Time and Money

MANUFACTURED BY

WARE COUPLING & NIPPLE CO.

WARE, MASS., U. S. A.



40 Years Old—Still Serving!

In the life of a pipe line, forty years is a long time — particularly if it is spent underground, subject within and without to corrosive onslaughts.

The pipe that can stand it is the pipe for service lines. That genuine wrought iron pipe has the necessary endurance is clearly demonstrated by service records all over the country of which the above photograph is an interesting example.

Here is a two-foot section from a line laid in 1886 by the Atchison Water Co. It is still good. It was removed simply to admit a valve. The line as a whole is in its 41st year of constant, uninterrupted service.

For sixty years, Byers has made pipe from genuine wrought iron. Its quality today is no less than that which has already defied rust for two, even three generations. Such, surely, is the ideal pipe for service lines.

A. M. BYERS COMPANY

Established 1864 — Pittsburgh, Pa.

BYERS PIPE

GENUINE WROUGHT IRON

W. B. Hubbard & Sons Co.

FRANK W. HUBBARD, President-Treasurer
WALLACE R. HUBBARD, Assistant Treasurer

WATER WORKS SUPPLIES

176 Oliver Street, Boston, Mass.

PIERCE-PERRY CO.

SUCCESSORS TO
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JOBBERS OF
Heating and Plumbing Supplies
Steel, Wrought Iron and Brass Pipe
Water Works Materials

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BOSTON PIPE & FITTINGS CO.

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Byers Genuine Wrought Iron Pipe

National Pipe

COMPLETE LINE OF WATER WORKS SUPPLIES

273-279 CONGRESS ST., BOSTON

We Carry in BOSTON STOCK for Immediate Shipment

CAST IRON BELL AND SPIGOT WATER PIPE AND FITTINGS
FLANGED PIPE in full and short lengths
WROUGHT PIPE

FRED A. HOUDLETTE & SON
(Incorporated)

40 Central Street, Boston, Mass.

Quotations furnished promptly for shipment from Foundry

CEMENT LINED SERVICE PIPE

With Specially Adapted Lead-lined Fittings

Also Curb Cocks which eliminate Iron to Brass Corrosion both inside and out.

CEMENT LINED PIPE CO.
LYNN, MASS.

SUMNER & DUNBAR

Manufacturers of and Dealers in
S. & G. Water Works Brass Goods
Byers' Wrought Iron Pipe
Service and Valve Boxes
Cast Iron Pipe and Fittings

12-18 Pittsburgh Street - - Boston, Mass.
Telephone, Liberty 1350

R. D. WOOD & CO.

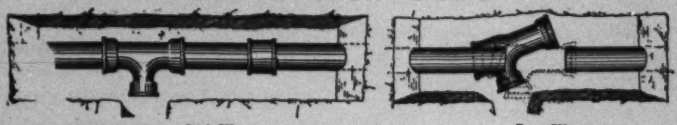
400 CHESTNUT STREET, PHILADELPHIA, PA.

Engineers, Iron Founders and Machinists

HYDRAULIC VALVES and MACHINERY

Cast Iron Pipe

CUTTING-IN TEES

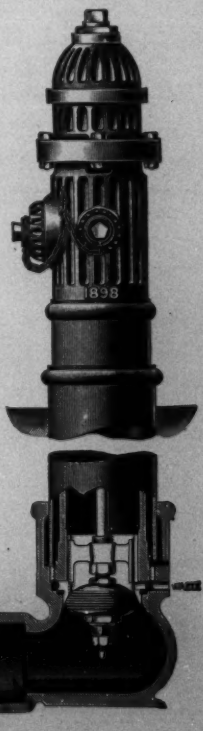


Old Way *Our Way*

Connections economically and easily made with one fitting. Saves sleeve, cuts, lead and unnecessary work and material.

"Reduced Specials"

Cost of fittings reduced from 25% to 50%. Full strength. Deep bells. Convenient to handle. Sold by the piece.



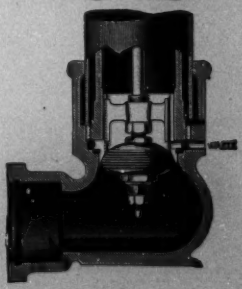
Mathews Fire Hydrants

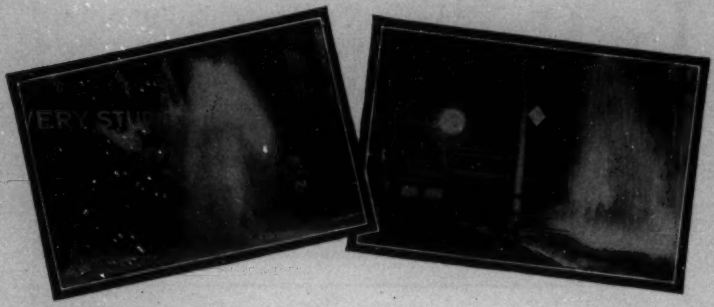
A half century of use has established their reputation as being the most economical, durable and simple hydrant.

Number in use exceeds total of all other makes combined.

Gate Valves

R. D. WOOD & CO. STANDARD
DOUBLE DISK
ANTI-FRICTION
EXTRA WEIGHT, FINISH
AND MATERIAL





Needless floods—

50th Anniversary 1877-1927

There can be no damage from water when a Kennedy Fire Hydrant is broken.

THOUSANDS of fire hydrants are broken every year in cities and towns throughout the country. It seems impossible to prevent these accidents, but in your locality you can at least limit the damage to the hydrants themselves by standardizing on the Kennedy "Newtype" Fire Hydrant, which automatically remains tightly closed against the flow of water even if the top is completely broken off.

Kennedy Hydrants are fool-proof and frost-proof as well as flood proof. All operating parts are fully enclosed within the cover where they are safe from tampering, and positive action drip valves keep the standpipe completely drained and avoid freezing.

Kennedy Fire Hydrants conform strictly with American Water Works Association Specifications, and their many advantages and reliable operation have won for them the hearty approval of Fire Chiefs and Water-Works Superintendents all over the country.

The Kennedy Valve Mfg. Co.
Elmira, N. Y.
Branches in principal cities

KENNEDY

VALVES-PIPE FITTINGS-FIRE HYDRANTS

Automatic Pressure Control Valves
Feed Water Filters
Portable Fire Hydrant Heads
Hydraulic Engines
Hydraulic Booster Pumps

ROSS VALVE MFG. CO., INC. TROY, N. Y.
ESTABLISHED 1879

Coffin Valve Co.

NEPONSET, MASS.

Sluice Gates, Gate Valves and Fire Hydrants

Health and Protection First

Water delivered through dirty pipes may be a MENACE.

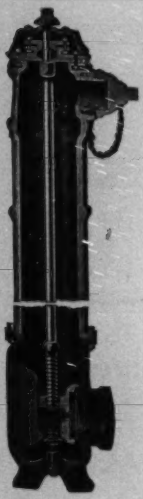
Incrusted water pipes mean inefficiency and loss of Fire Protection.

We Guarantee the Results of Our Method of Cleaning.

WRITE US.

National Water Main Cleaning Co.

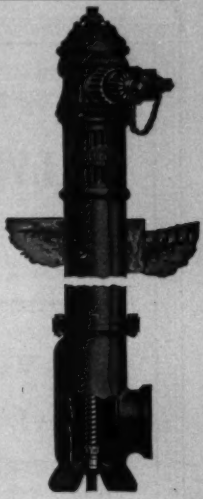
50 Church Street New York City



LUDLOW VALVE MFG. CO.

MANUFACTURERS OF

VALVES and FIRE HYDRANTS



This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.

The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.

DOUBLE AND SINGLE GATE **VALVES,**

ALSO CHECK **VALVES,**

FOOT **VALVES.**

FIRE HYDRANTS.

YARD, WASH, AND FLUSH HYDRANTS.

☞ SEND FOR CIRCULARS ☜

OFFICE AND WORKS: FOOT OF ADAMS STREET, TROY, N. Y.

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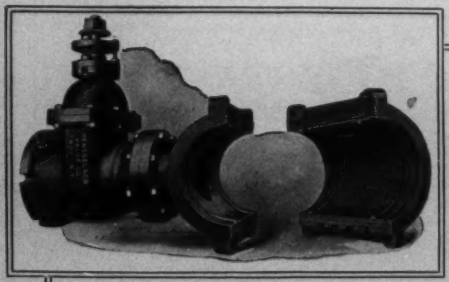

Rensselaer Tapping Sleeves

were brought out to meet a growing demand for a "BETTER" Tapping Sleeve. They were designed to suit conditions met in actual practice.

They can be used with all standard makes of Tapping Machines.

POINTS OF
SUPERIORITY

Have two lead rings.

Require less lead for calking.

Iron washers not required.

Bolting flanges are made full length of sleeve, giving great strength.

Have greater thickness of hubs on ends.

Easier to center on pipe before pouring lead.

Cost less to install.

Book No. 11 gives full information.

Ask for prices.

CHARLES L. BROWN
New England Sales Manager, Lock Box 2, Northboro, Mass.

RENSSELAER VALVE COMPANY, TROY, N.Y.

THE CHAPMAN VALVE MANUFACTURING COMPANY

Manufacturers of

Gate Valves Drip Valves

Gate Fire Hydrants

Corporation Cocks Curb Cocks

Anderson Couplings

Lead Pipe Connections

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Type of Eddy Hydrant Popularly Used

More Than Sixty Years of Experience Goes Into All

EDDY

Hydrants and Valves

BUILT TO MEET EVERY EXACTING REQUIREMENT OF WATER-WORKS SERVICE

Practical water-works men instantly recognize the superior features of Eddy products. For instance, with the hydrant.

A damaged valve can be replaced in a few minutes — Water hammer is avoided by the valve closing against the pressure and the use of the cut-off under the valve, which gradually closes it —
Stems cannot be bent in closing the hydrant.
Nothing can lodge on the valve seat to prevent closing of the valve —
The Drip Rod can be removed without interfering with the hydrant in any manner —
The position of the stem of the hydrant indicates accurately the position of the valve —
Whatever can pass the valve opening will pass the standpipe —
No frost case necessary —
All of these points are explained thoroughly in our catalogue, which will pay you to study.

The Eddy Valve, Too

Has its distinctive and individual features. The double disk gates are free to adjust themselves in different positions every time the valve is closed, thereby keeping smooth and tight faces. And two bronze hooks on the ball loosely engage with the gates to prevent them from spreading at the top. The center bearing gates are forced to their seats with equal pressure at all points. There is a good deal more worth knowing about Eddy Valves. Further details will be sent for the asking.

Other Eddy Products

The Eddy line of water-works products also includes horizontal and vertical check valves, foot valves, hydraulically operated valves, indicator posts, etc.
All goods made by the Eddy Valve Company are manufactured exclusively at Waterford, New York.

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WATERFORD, N. Y., U. S. A.

EMAUS PIPE FOUNDRY,
DONALDSON IRON CO.,

MANUFACTURERS
...OF...

CAST IRON PIPE

...AND...

Special Castings for Water and Gas.
Also Flange Pipe, Street Castings,
Manhole Heads and Covers, etc.

J. G. EBERLEIN, President and Treasurer.
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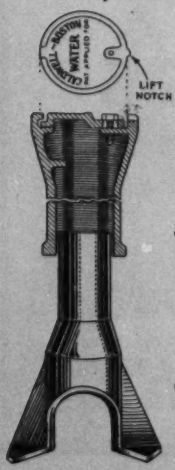
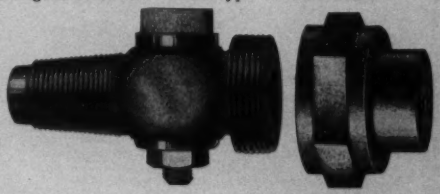
EMAUS,
LEHIGH COUNTY, PA.

The "BEST" Cast Iron Curb Box

Top section is interchangeable with the "Slide Type" Buffalo Box



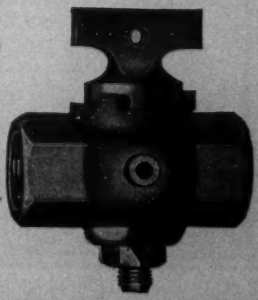
No change necessary in wrench or shut off keys



"CALDWELL" Water Works
Brass Goods, Curb and
Valve Boxes

None better and few as good

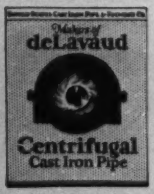
GEORGE A. CALDWELL CO.
Mattapan Square
BOSTON, MASS.



In laying deLavaud Centrifugal pipe, the plain end slides forward, riding on the tapered shoulder inside the bell until it automatically centers itself.

deLavaud Centrifugal pipe is self-centering—easy to lay

THIS pipe is equipped with bell and plain end joint similar to the type used by the Metropolitan Water Board of London, England. Once in place and caulked in the usual manner, these joints show unusual resistance to blowing out and are most flexible.



Write for literature covering the specifications and use of deLavaud Centrifugal Cast Iron Pipe

United States Cast Iron Pipe and Foundry Company

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THE A. P. SMITH MANUFACTURING CO.

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Manufacturers of

Tapping Machines, Fire Hydrants, Water Gates,

Economic Lead Furnaces,

Corporation and Curb Cocks, Brass and Aluminum Castings.

Also General Supplies for Water and Gas Works.

Write for Catalogue.

NICHOLAS ENGEL

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CAST IRON

WATER & GAS PIPES

FLANGE PIPE

Special Castings, Fire Hydrants, Valves

General Foundry and Machine Work

WOOLWORTH BUILDING 233 BROADWAY

NEW YORK CITY

HIGHEST AWARD, GOLD MEDAL, ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments

use

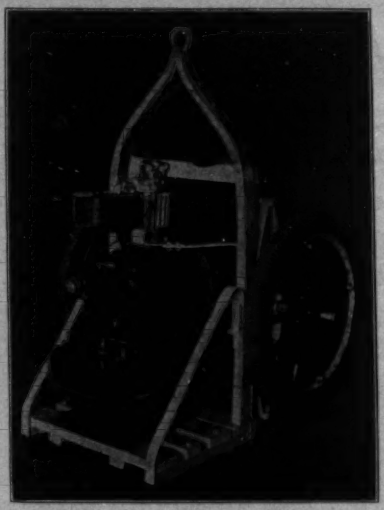
LEAD-LINED IRON and TIN-LINED PIPES

for their service connections

MANUFACTURED BY

Lead Lined Iron Pipe Company

Wakefield Mass.



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Light
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Bell and Spigot Flanged Pipe
Special Castings
Flexible Joint Pipe Cylinders

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LARGE STOCK ENABLES US TO MAKE QUICK SHIPMENTS

TRADE **"LEADITE"** MARK

Registered U. S. Pat. Office

"The World's Playground" has used Leadite with complete satisfaction for over 20 years

ATLANTIC CITY, New Jersey, is proud of its well-paved streets. In laying new or additional cast iron mains, the engineers always use Leadite. They know from the experience of nearly one-quarter of a century that Leadite joints are absolutely secure and that the occasion will not arise where paved streets have to be dug up to repair the line.

In addition to the mains under the paved streets, Leadite was used for jointing the 24" main that runs under the famous boardwalk.

Other lines run through salt marshes, over bridges and under numerous railroad tracks.

The sizes of these mains run from 4" to 48".

Mr. L. Van Gilder is Engineer and Superintendent of the Atlantic City water department.

Added to the security and permanence of Leadite joints there is a saving of 75%.

For its economy—permanence—security—and the speed with which jointing can be finished—Water Works men specify and use Leadite.

Laying 24" c. i. water mains, with Leadite Joints, in Atlantic City under paved street.

Specify and use LEADITE —it saves at least 75%

Be sure it is LEADITE and accept no imitations : :

The pioneer self-caulking material for c. i. pipe. Tested and used for over 30 years.

THE LEADITE COMPANY Land Title Bldg. PHILADELPHIA, PA.

NO CAULKING

Chadwick-Boston Lead Co.

800 Albany St., Boston

Agents for

The Celebrated "ULCO"

LEAD WOOL

(Every Atom Pure Lead)

For calking pipe joints under the most difficult conditions.

For overhead joints, or in wet places where the use of molten lead is not only impracticable but dangerous — **LEAD WOOL** may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe without danger of a leak.

As compared with the poured joint, in this respect, the superiority of **LEAD WOOL** is apparent.

Manufacturers of

Lead Pipe, Tin Lined Lead Pipe, Pure Block-Tin Pipe, Solder, White Lead and Red Lead.

HIGHEST QUALITY SOFT BRANDS

PIG LEAD

TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND

Join Your Water Mains

WITH

LEAD-HYDRO-TITE

TRADEMARK

AND CUT YOUR EXPENSES

50% FIRST COST

50% SMALLER BELL HOLES

75% HANDLING

100% CALKING

OUR PROPOSAL

That the prospective users purchase a trial lot of 1 to 5 bags, and that this be used under the direction and according to the instructions of our representative.

If, after a trial, the purchaser is not satisfied with the material, any surplus not used to be returned to the Hydraulic Development Company, and no charge to be made for any of the Hydro-Tite furnished.

Owned, Manufactured and Sold by New Englanders

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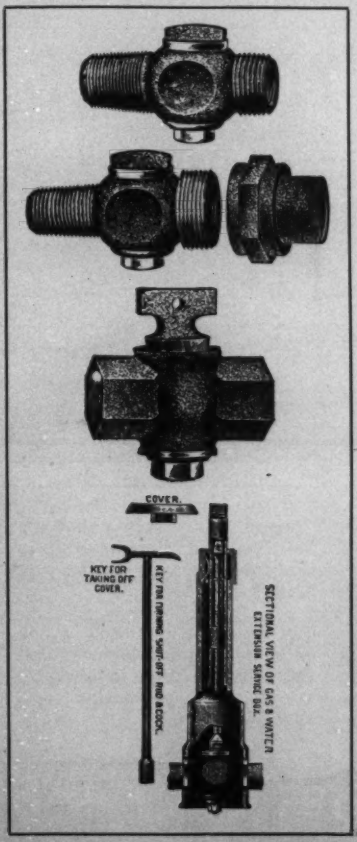
Chicago, Illinois

TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND

"The Goods That Please"



Corporation and Curb Cocks

We have them to meet every requirement

ORIGINAL

"Hays-Erie"

Extension Service Boxes of proven advantages

Let us send at our risk, on 30 days' trial, a

Payne's Patent Tapping Machine

which is recognized to be the most easily operated owing to the few working parts.

Hays Mfg. Co., ERIE PENNSYLVANIA

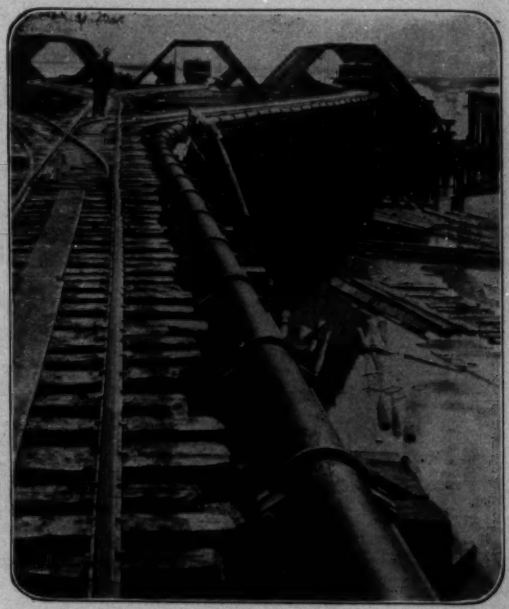
Established 1869

No Hot Lead

No Cold Lead

'Universal' lines stay tight because they're all-cast iron

easier quicker safer !



ACCLAIMED by water works engineers and superintendents as the highest development in cast iron pipe. Thousands of miles laid the country over every year.

No joints to calk. No lead substitutes. Nothing to deteriorate, nothing to work loose in its machine-tapered iron-to-iron joints—joints that are flexible and dependable—*as tight as the wall of the pipe itself.*

Let us show you how much more dependable and economical Universal Pipe is for water supply, fire protection and sewage disposal.

UNIVERSAL CAST IRON PIPE

No bell holes to dig. No joints to calk

THE CENTRAL FOUNDRY COMPANY

Subsidiary of The Universal Pipe and Radiator Company

Graybar Building, 420 Lexington Avenue

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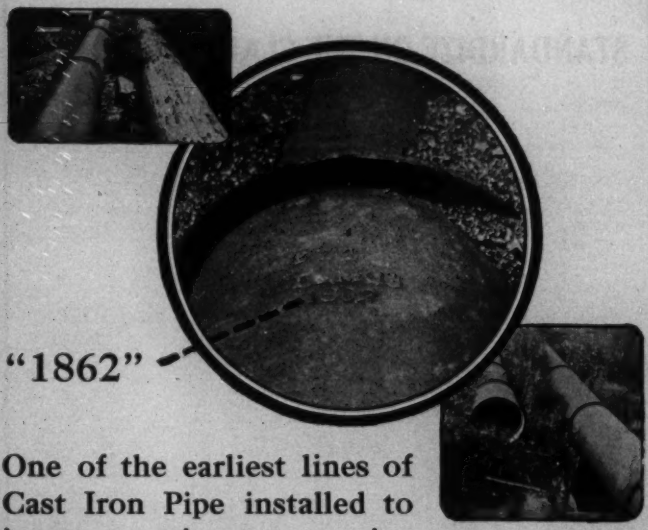
SERVICE BOXES
WITH *STAY-ON* COVERS

Just what you have been waiting for . . . Interchangeable with "Buffalo" boxes . . . .

Ask for CATALOG



"1862"

One of the earliest lines of Cast Iron Pipe installed to insure continuous service

This line runs across salt marshes. It demonstrates the high resistance of Cast Iron Pipe to corrosion.

After sixty-five years under these conditions, the line shows not the slightest sign of weakness anywhere.

Write for U. S. Cast Iron Pipe handbook. It contains necessary data for construction engineers.

United States Cast Iron Pipe and Foundry Company

General Offices:
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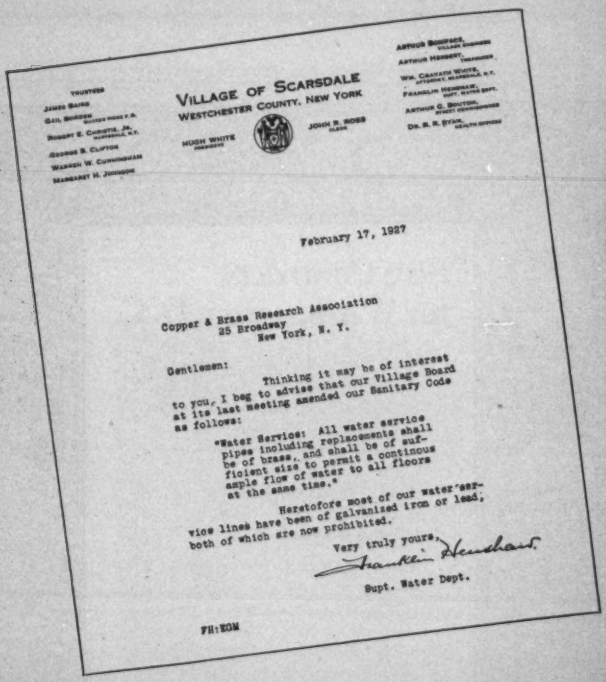

VILLAGE OF SCARSDALE
WESTCHESTER COUNTY, NEW YORK

February 17, 1927

Copper & Brass Research Association
25 Broadway
New York, N. Y.

Gentlemen:

Thinking it may be of interest to you, I beg to advise that our Village Board at its last meeting amended our Sanitary Code as follows:

"Water Service: All water service pipes including replacements shall be of brass, and shall be of sufficient size to permit a continous ample flow of water to all floors at the same time."

Heretofore most of our water service lines have been of galvanized iron or lead, both of which are now prohibited.

Very truly yours,
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Supt. Water Dept.

FH:EGM

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The Journal of the New England Water Works Association

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